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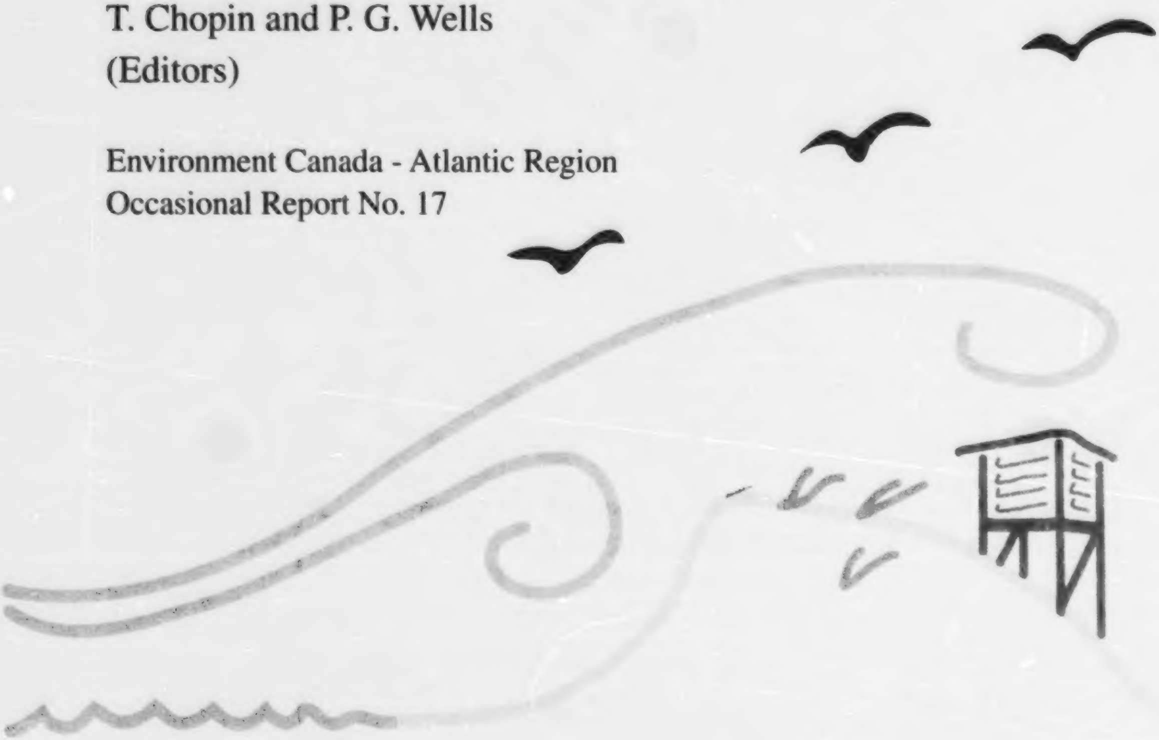
Opportunities and Challenges for Protecting, Restoring and Enhancing Coastal Habitats in the Bay of Fundy

Proceedings of the 4th **Bay of Fundy Science Workshop**,

Coastal Zone Canada 2000 International Conference,
Trade and Convention Centre
Saint John, New Brunswick, Canada, September 19-21, 2000

T. Chopin and P. G. Wells
(Editors)

Environment Canada - Atlantic Region
Occasional Report No. 17



An Invitation to Participate in the 5th Bay of Fundy Science Workshop, May 13-16th, 2002.

Health of the Bay of Fundy: Assessing Key Issues

Environmental Sciences Research Centre, Acadia University, Wolfville, NS.

This workshop is the fifth in the series on the Bay of Fundy, organized by BOFEP (Bay of Fundy Ecosystem Partnerships). The theme will be the health of the Bay's ecosystems, living resources (wildlife, fisheries) and coastal communities. It will emphasize progress we have made or are striving to make in recent years on the many environmental and resource issues facing the Bay. The Workshop offers participants the opportunity to present original research papers, synoptic reviews, discussion or viewpoint papers, and special working sessions/discussion groups on any aspect of the Bay of Fundy, within the general theme. These could include physical, chemical and biological oceanography; marine and human ecology; fisheries; wildlife biology and ecology; human uses of the bay and impacts of those uses; marine environmental quality and ecosystem health/integrity; marine protected areas, wildlife reserves and parks; and coastal issues of particular concern to the Bay's human inhabitants and communities. The hope is that there will be wide participation and discourse on issues with social and scientific dimensions, important to the sustainability of the Bay of Fundy. Collectively, we wish to evaluate progress since the first workshop in 1996, and identify new directions and projects.

Special concurrent sessions have been suggested for the Workshop -

1) Health Indicators for the Bay of Fundy and Gulf of Maine;
2) The Biology and Ecology of *Corophium* spp.;
3) Species and Habitats at Risk in the Bay of Fundy;
4) Minas Basin - Community Issues and Actions;
5) Adaptation of Coastal Communities to Climate Change;
6) Watershed Issues Around the Bay of Fundy.

Other topics are welcomed. We are currently seeking volunteers to organize and run the special sessions. Their success depends on you!

All suggestions for the Workshop are welcomed. Review papers are needed. Sessions for contributed papers, posters and project demonstrations are being planned. Student, non-government organization, coastal community and First Nation participation is especially welcomed. **Abstracts for submissions are due at the BOFEP Office, November 30th, 2001. Review and discussion papers will be circulated before the Workshop. A reviewed proceedings will be published.**

The workshop is currently being organized by members of the BOFEP Management and Steering Committees. It's primary sponsors so far are BOFEP, Environment Canada, Fisheries and Oceans Canada (Bedford Institute of Oceanography), Sea Pen Communications, and the Acadia Centre for Estuarine Research (ACER, Acadia University). Other supporting sponsors are most welcome.

For further and updated information, please visit the BOFEP Web Site - www.auracom.com/~bofep; contact the BOFEP Office or Graham Daborn at ACER (ph 902-585-1113/1118); or contact Peter Wells, Workshop Co-Chair, Environment Canada, Dartmouth, NS (ph 902-426-1426 or peter.wells@ec.gc.ca).

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BoFEP
BAY OF FUNDY
Ecosystem Partnership

4th Bay of Fundy Science Workshop

Opportunities and Challenges for Protecting, Restoring and Enhancing Coastal Habitats in the Bay of Fundy

Held as part of the
Coastal Zone Canada 2000 International Conference
September 19-21, 2000
Trade and Convention Centre
Saint John, New Brunswick, Canada

Proceedings

T. Chopin and P.G. Wells
(Editors)

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We are pleased to acknowledge the support and assistance of many individuals who contributed to the success of the 4th Bay of Fundy Science Workshop, held as part of the Coastal Zone Canada 2000 International Conference.

First, special thanks to the Organizing Committee:

- Chair: Thierry Chopin
- Programme Committee: Thierry Chopin
  Graham Daborn
  Peter Hicklin
  Jon Percy
  Peter Wells
- Workshop Secretariat: Judy McCrory
- Student Assistant: Kimble Costain

Second, the Organizing Committee would like to thank the following for their financial, or in-kind, sponshorship of this workshop:

- Bay of Fundy Ecosystem Partnership
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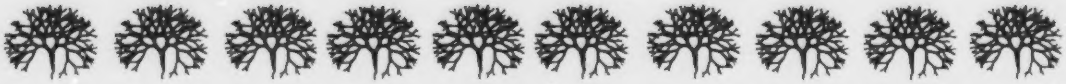
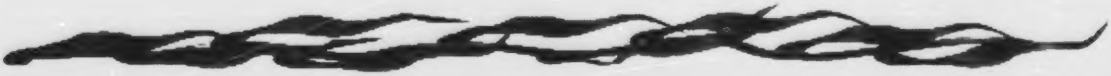
- Coastal Zone Canada Association
- Environment Canada
- Centre for Coastal Studies and Aquaculture/University of New Brunswick - Saint John
- Kathy, Marine and Morgan Chopin



INTRODUCTION



INTRODUCTION

T. Chopin

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The 4th Bay of Fundy Science Workshop was held in Saint John, New Brunswick, on September 19-21, 2000, as part of the Coastal Zone Canada 2000 International Conference on September 17-22, 2000.

It continued the series of meetings organized by the Bay of Fundy Ecosystem Partnership (BoFEP). The BoFEP is a "virtual institute" whose vision is to:

a. promote the ecological integrity, vitality, biodiversity and productivity of the Bay of Fundy ecosystem, in support of the social well-being and economic sustainability of its coastal communities;
b. facilitate and enhance communication and co-operation among all citizens interested in understanding, sustainably using and conserving the resources, habitats and ecological processes of the Bay of Fundy.

The goal of the 1st Workshop, held in Wolfville, Nova Scotia (January 29-February 1, 1996), was to seek a consensus on further marine ecosystem research needed on the Bay's natural resources, to identify coastal management and conservation requirements for the Bay, and to map out a plan for timely, multi-partner, interdisciplinary research and coastal management initiatives. The proceedings of this Workshop were published in Percy *et al.* (1997).

The goal of the 2nd Workshop, held in St. Andrews, New Brunswick (November 11-15, 1997), was to consider the role of coastal monitoring and subsequent assessment in understanding the ecological processes and biota of coastal environments and the changes occurring in them. The proceedings of this Workshop were published in Burt and Wells (1998).

The goal of the 3rd Workshop, held in Sackville, New Brunswick (April 22-24, 1999), was to consider a multitude of facets related to understanding change in the Bay of Fundy ecosystem. The central questions of the Workshop were: how can we recognize change, what tools are needed to monitor change, and most importantly, how should we respond to change? The proceedings of this Workshop were published in Ollerhead *et al.* (1999).

The goal of the 4th Workshop was to consider opportunities and challenges for protecting, restoring and enhancing coastal habitats. While focussing specifically on the Bay of Fundy, presentations were appropriately integrated with the overall theme of the Coastal Zone Canada 2000 International Conference "Coastal Stewardship: Lessons Learned and the Paths Ahead", and especially the sub-theme "Coastal Health". The 4th Bay of Fundy Science Workshop was particularly well attended as a result of meeting jointly with the Coastal Zone Canada 2000 International Conference, which hosted almost 600 delegates from over 50 coastal nations.

The 5th Bay of Fundy Science Workshop will be held in Wolfville, Nova Scotia, May 13-16, 2002. Further information about the BoFEP may be obtained by contacting:

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Percy, J.A., P.G. Wells and A.J. Evans (Eds.). 1997. Bay of Fundy Issues: A Scientific Overview. Workshop Proceedings, Wolfville, N.S., January 29 to February 1, 1996. Environment Canada, Atlantic Region Occasional Report No. 8, Environment Canada, Sackville, New Brunswick, 191 pp.

Burt, M.D.B. and P.G. Wells (Eds.). 1998. Coastal Monitoring and the Bay of Fundy. Proceedings of the Maritime Atlantic Ecozone Science Workshop, St. Andrews, New Brunswick, November 11-15, 1997. Huntsman Marine Science Centre, St. Andrews, New Brunswick, 196 pp.

Ollerhead, J., P.W. Hicklin, P.G. Wells and K. Ramsey (Eds.). 1999. Understanding Change in the Bay of Fundy Ecosystem. Proceedings of the 3rd Bay of Fundy Science Workshop, Mount Allison University, Sackville, New Brunswick, April 22-24, 1999. Environment Canada, Atlantic Region Occasional Report No. 12, Environment Canada, Sackville, New Brunswick, 143 pp.

CASE STUDIES/WORKSHOPS

Session One

NUTRIFICATION OF COASTAL WATERS

Chair: Thierry Chopin, University of New Brunswick,
Saint John, New Brunswick

NUTRIENT OVER-ENRICHMENT OF SOUTH FLORIDA'S CORAL REEFS: HOW SCIENCE AND MANAGEMENT FAILED TO PROTECT A NATIONAL TREASURE

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Introduction

The Florida Keys are the most popular SCUBA diving and snorkeling destination in the world. The primary attraction is the 220-mile long Florida Reef Tract (FRT), the only living coral reef ecosystem within the continental United States, which attracts some 2.5 million tourists a year. Coral reefs are among the most productive and diverse ecosystems in the world and, as such, are comparable to their terrestrial counterparts -- tropical rainforests. Coral reefs grow as a thin veneer of living coral tissue on the outside of the hermatypic (reef-forming) skeleton and accrete massive limestone formations over geologic time. Coral reefs have evolved over hundreds of millions of years in tropical and subtropical waters that typically have very low concentrations of dissolved inorganic nutrients. Under such conditions, corals recycle limited nutrient supplies via a symbiosis in which the host coral releases waste dissolved nutrients that are tightly recycled by the symbiotic zooxanthellae algae -- which in turn provide carbon-rich compounds to the coral. The calcification process in corals also generates protons, which provide for co-transport of nutrients into the corals, providing these reef-builders with a competitive advantage over fleshy, non-calcareous algae under low nutrient conditions. Because of the ability of corals to thrive in nutrient-poor surface waters of tropical oceans, ecologists refer to them as "oases in ocean deserts".

Scientists have long known that even slight increases in nutrient concentrations from sewage and other land-based human activities can have catastrophic effects on the health of coral reefs. Nutrient enrichment increases the growth and respiration rate of the nitrogen-limited symbiotic zooxanthellae, which decreases the photosynthesis to respiration ratio in corals and leads to physiological "stress". Nitrogen-enriched growth of zooxanthellae also alters the biochemistry of the symbiosis by shifting algal photosynthesis towards production of protein at the expense of carbohydrate – undermining the functional nutrition of the symbiosis (ironically, the coral starves under high nitrogen conditions). Nutrient enrichment can also result in increased cover of soft corals (non-hermatypic), as well as blooms of macroalgae (> 2 cm high) and endolithic filamentous algae, all of which outcompete and physically overgrow more slowly growing reef-forming hard corals. Elevated nutrients reduce overall reef growth by reducing calcification in corals, both directly and indirectly by reducing light and photosynthesis (which is directly linked to calcification) due to shading by macroalgae, turf algae, and increased light attenuation of the water column from increased phytoplankton biomass and turbidity. Nutrient enrichment also leads to increased abundance of herbivores and corallivores, including parrotfish, sea urchins, and "Crown-of-Thorns" starfish that can reduce living coral cover and accelerate bioerosion of limestone reef frameworks.

Recognition of regional eutrophication in the Florida Keys

Beginning in the late 1970's and early 1980's, hard coral cover began to decline with parallel increases in algal turf, macroalgae, and soft corals on patch and bank reefs of the FRT. This biotic phase-shift correlated with increasing human activities and associated nutrient loads from the Florida Keys that included deforestation, fertilizer use, sewage inputs, and fossil fuel combustion. In addition, a major change in water management policy in South Florida occurred in the late 1970's. This involved diverting massive flows of stormwater runoff from the Everglades Agricultural Area (EAA) southward towards Everglades National Park (ENP) and Florida Bay, rather than backpumping into Lake Okeechobee that was causing hypereutrophication of the "Big Lake". Scientists documented the impacts of the increased nitrogen and phosphorus loads on eutrophication of the oligotrophic sawgrass and periphyton communities of ENP as commercial fishermen reported the expansion of macroalgae and phytoplankton blooms in seagrass meadows of Florida Bay. SCUBA divers on downstream reefs in the Florida Keys reported decreased visibility and the first coral bleaching of the FRT on reefs offshore Key West in summer of 1980. Heavy rains and high Everglades flows associated with the 1982-83 El Nino were followed by "white band" disease that caused widespread loss of elkhorn (*Acropora palmata*) and staghorn (*Acropora cervicornis*) corals while "black band" disease began eroding coral tissue on mountain (*Montastrea* spp.) and brain corals (*Diploria, Colpophyllia*). In summer of 1987, a massive die-off of turtle grass (*Thalassia testudinum*) began in central Florida Bay coincident with the first massive coral bleaching throughout the FKNMS.

In response to the deteriorating water quality, loss of coral cover, and ecological problems in Florida Bay and the Florida Keys, over 50 scientists, educators, and managers attended a NOAA sponsored research and management workshop in Key Largo in June 1988. Rankings were made by the attendees as to the major threats and problems facing coral reefs of the Florida Keys. Although anchor damage by boaters had been considered the primary problem facing coral reefs in the 1970's, attendees now concluded that excessive nutrient loading and eutrophication was the top priority issue to be addressed to protect the coral reefs: "Excessive nutrients invading the Florida Reef Tract from the Keys and Florida Bay are a serious and widespread problem" (NOAA 1988). A primary concern of attendees of that workshop was whether or not their recommendations would be implemented and funded. Widespread attention to the declining status of South Florida's coral reefs occurred in 1990 when *National Geographic* featured the article "Florida's Imperiled Coral Reefs" that specifically noted the growing problem of nutrient pollution, algal blooms, and reef coral die-off.

The international attention to the decline of coral reefs in South Florida helped to spur passage of the Florida Keys National Marine Sanctuary (FKNMS) and Protection Act on November 5, 1990, to "provide long-term protection to the coral reef resources of the Florida Keys". Uniquely, the FKNMS Act included an inter-agency (USEPA, NOAA) Water Quality Protection Program

(WQPP) intended to protect south Florida's coral reefs from further water quality degradation. The WQPP, which was implemented by USEPA, was intended to: 1) develop a monitoring program for water quality, coral reef communities, and seagrasses to determine "status and trends" and 2) recommend priority corrective actions and compliance schedules addressing point and non-point source pollution to restore and maintain the chemical, physical, and biological integrity of the FKNMS. During Phase I of the WQPP, information was compiled and synthesized on the status of water quality in the FKNMS and Florida Bay. Despite existing scientific knowledge of the role of nitrogen-rich runoff from the Everglades in fostering phytoplankton blooms, turbidity, and seagrass die-off in Florida Bay, the USEPA Phase I Report concluded: "even though the ultimate cause of the present seagrass die-off has yet to be proven conclusively, it seems clear that anthropogenic nutrient input to the surface water is not responsible" (USEPA 1991).

While USEPA's Phase I Report (1991) categorically dismissed the role of nutrient enrichment and eutrophication to the ecological problems of Florida Bay, the report alternatively promoted the hypothesis that the seagrass die-off resulted from "hypersalinity". The report claimed that draining of the Everglades caused the diversion of freshwater from Florida Bay, resulting in salinities of 55 ppt in central Florida Bay that were "fatal" to seagrasses. Actually, the high salinities in central Florida Bay referred to in the Phase I Report during the late 1980's were a result of a drought when South Florida received annual rainfall that was ~ 30-40 % lower than normal several years in a row. Experimental studies decades earlier by McMillan and Moseley (1967) showed that *T. testudinum*, the seagrass that was dying off, could grow at salinities up to at least 60 ppt, higher than the salinity of 55 ppt which the Phase I report claimed was "fatal" to seagrasses. Furthermore, the long-term studies of Tabb *et al.* (1962) decades earlier concluded that *T. testudinum* thrives under hypersaline conditions in Florida Bay by stating "with marked reduction in salinity beginning in the winter of 1957 and ending in 1960, the *Thalassia* underwent decline in size and abundance ...they did not return in abundance until the drought of 1961-62, reaching peak growth and coverage in the spring of 1962. Thus it appears that long periods of near or slightly above normal salinities are a requirement for maximum growth of *Thalassia*".

Politics as usual: go with the flow

Despite existing knowledge that hypersalinty was not the real problem and that nitrogen-rich runoff from the Everglades was the more likely factor underpinning the decline in water quality and seagrass die-off in Florida Bay, a political decision was made by water managers and cognizant government agencies to "restore" Florida Bay by pumping more nitrogen-rich water from the Everglades into the bay. Political support for this decision grew from the Everglades Lawsuit (that led to the Everglades Forever Act) that recognized phosphorus but not nitrogen pollution of the Everglades from the agricultural activities in the EAA. The Everglades Forever Act called for increased flows of low phosphorus water into the Everglades and Florida Bay as the primary basis for "Everglades Restoration". Ironically, expensive practices to remove phosphorus in and around the EAA by sugarcane farmers and the South Florida Water Management District's (SFWMD) "Stormwater Treatment Areas" (STA's) will increase the nitrogen loading to downstream waters of the ENP and Florida Bay because of decreased plant growth and nitrogen removal in the Everglades wetlands as a result of greater phosphorus limitation of plant growth.

Increasing fresh water flows and associated non-point source nitrogen pollution of Florida Bay and downstream waters of the FRT became a "high priority" of the FKNMS Management Plan/Environmental Impact Statement (NOAA 1996). Curiously, while the FKNMS management plan promoted policies that increased regional nitrogen pollution from agricultural activities in the Everglades, it also gave a "low priority" to monitoring domestic wastewater surface discharges into the FKNMS (NOAA 1996). Research by the Florida Department of Environmental Protection and other scientists had documented, in great detail, the ecological and public health impacts of sewage-driven eutrophication and bacterial contamination of surface waters of the FKNMS. However, expensive remedial actions such as Advanced Wastewater Treatment (including nutrient stripping) were a volatile and controversial issue in the Keys at that time due, in large part, to a growing lack of confidence in the FKNMS process. A referendum vote in Monroe County (Florida Keys) in 1996 found 54 % of the voters against NOAA and the FKNMS Management Plan -- although the vote was non-binding. The regional eutrophication problem appears to have exacerbated local sewage contamination in the Florida Keys as high fecal coliform counts in the past several years have resulted in numerous and extended beach closures from Key Largo to Dry Tortugas.

The lack of confidence by the local community in the FKNMS was directly related to the worsening of regional water quality with implementation of the FKNMS "restoration" plan for Florida Bay. The FKNMS management plan was promoted by several national NGO's (Audubon Society, Nature Conservancy, Wilderness Society, Environmental Defense Fund) who joined the political bandwagon to "flood the bay". Scientific consultants to ENP had misrepresented the quality of water flowing through the Everglades as "distilled water" (Iannotta 1996) when, in fact, the water in Shark River Slough averaged ~ 100 µM total nitrogen. Beginning in 1991, increased freshwater discharges from both Shark River Slough and Taylor Slough in the ENP (Rudnick *et al.* 1999) correlated significantly with decreased salinity throughout the bay and increases in ammonium (central bay), phytoplankton biomass (chlorophyll a, western bay), and turbidity (bay-wide, Boyer *et al.* 1999). Between 1991 and 1996 average salinity in Florida Bay decreased from 41 ppt to 23 ppt, a 44 % decrease in bay-wide salinity. Following the decreased salinity and increase in ammonium in 1991-1992, cascading ecological disturbances in the bay included a massive cyanobacterial bloom (*Synechococcus*) that was followed by a sponge die-off, further seagrass die-off, and the largest red tides to ever affect the FKNMS region.

Analysis of the Florida Bay data shows that the development of phytoplankton blooms in both the western and central bay followed the increased nitrogen loads and were most severe in central Florida Bay where the highest dissolved inorganic nitrogen (DIN) and chlorophyll a occurred. This is also the location where the initial seagrass die-off began in 1987. This spatial pattern supports the hypothesis that increased ammonium resulting from agricultural activities at the headwaters of both Shark River Slough and Taylor Slough were the primary DIN source (s) fueling the phytoplankton blooms in western and central Florida Bay (Lapointe and Clark 1992, Lapointe *et al.* 1993). These phenomena provide strong evidence that nitrogen enrichment, rather than hypersalinity, was the more important ecological factor causing the demise of *T. testudinum* in the bay. Contrary to the USEPA Phase I Report (1991), a recent NOAA National Estuarine Eutrophication Assessment ranked Florida Bay as having a "high" level of expression of eutrophic conditions, an index based on chlorophyll a, macroalgal abundance problems, epiphyte abundance problems, low dissolved oxygen, nuisance and toxic algal blooms, and loss of submerged aquatic vegetation (Bricker *et al.* 1999).

The net cumulative outflows from Florida Bay pass through the tidal channels of the middle and lower Florida Keys and flow west-southwest at ~ 4 cm/sec, impinging on the outer bank reefs of the FRT. Accordingly, the accelerated eutrophication of Florida Bay in 1991-1992 had downstream ecological effects that affected offshore bank reefs of the FRT. A long-term nutrient monitoring program at Looe Key National Marine Sanctuary (LKNMS) offshore Big Pine Key recorded maximum average concentrations of DIN (> 3 μM) in 1992, which coincided with peak DIN in central Florida Bay following the "first flush" of Everglades runoff since the drought of the late 1980's; this DIN concentrations at LKNMS is quite high compared to the annual mean DIN concentrations that averaged < 0.6 μM during the decade of the 1980's (Lapointe and Matzie 1996). Following this regional spike in DIN in 1992, both chlorophyll a and turbidity of the water column increased at LKNMS to maximum values (annual mean chlorophyll a of ~ 0.6 μg/l) in 1996 that coincided with peak flows from Shark River Slough. AVHRR satellite images showed very high reflectance values associated with the turbid, Florida Bay outflows that moved offshore and over the bank reefs, especially during the windy winter and spring months. The deteriorated water quality on offshore reefs coincided with an exponential increase in coral "disease" and die-off, reported as a 250 % increase between 1996 and 1997 (USEPA 1997).

Since the Everglades flush began in 1991-1992, DIN concentrations have averaged > 1 μM at LKNMS, indicating ~ 100 % increase in biologically available nitrogen at this offshore reef site (Lapointe *et al.* 2000). Bank reefs of the FRT had more than 70 % coral cover in the 1970's and now average ~ 15 % coral cover, or less. For example, the shallow fore reef at LKNMS, which was historically dominated by *Acropora palmata* and considered one of the Keys' top dive sites, now has less than 5 % coral cover. As coral cover has receded, turf algae, macroalgae have increased at LKNMS and other offshore reefs, collectively accounting for 48-84 % of benthic cover (Chiappone and Sullivan 1997). Dawes *et al.* (1999) recently reported a 67% decrease in macroalgal species diversity between 1964 and 1996 at the Content Keys in the lower Florida Keys as a result of nutrification; as the total number of species declined, nutrient indicator species such as the green algae *Ulva lactuca* and *Chaetomorpha brachygona* appeared.

Failing the "Everglades Test": what's next ?

Marjorie Stoneman Douglas, life-long advocate and protector of the Everglades' "River of Grass", once challenged that "the Everglades is a test; if we pass it, we get to keep the planet". Now, following a decade of expensive research, monitoring, and management by the FKNMS and numerous agencies involved with Everglades Restoration, it is useful to look back and assess what went wrong. Despite pre-existing knowledge and scientific consensus of a "serious" regional nutrient enrichment problem in Florida Bay and the FRT the late 1980's (NOAA 1988), the scientific and management community in the FKNMS process during the 1990's failed to respond in a timely manner to develop a nutrient source identification/evaluation/mitigation framework. The lack of a management framework to address the over-arching regional water quality degradation and mission of the FKNMS can be traced to at least four problems: 1) the lack of technically-trained resource managers that understood the basic coastal marine eutrophication problem, especially that in Florida Bay, 2) research dominated by marine biologists with reductive and often inaccurate or misleading (*e.g.* "hypersalinity hypothesis") approaches, rather than oceanographers or environmental scientists with systems approaches, 3) implementation of a spatially-extensive and expensive water quality monitoring program that had inadequate sampling frequency to detect year-to-year changes in even the most basic water quality parameters and conducted with no clear idea as to how the data would be used; and 4) scientists, managers, and policymakers involved with Everglades and Florida Bay "restoration" worked within a framework controlled by "top-down" political forces and land-use issues, which undermined a search for "scientific truth" by an otherwise objective "bottom-up" approach (Popper 1994).

Two critical aspects of any environmental risk assessment are "getting the right science" and "getting the science right". The failure in these two key steps by scientists and managers in South Florida during the 1990's were primary factors enabling the protracted time frame in which the severe water quality degradation described above has been (and continues to be) neglected. Hopefully, this case study will serve to inspire those in other coastal regions, especially in similar regions with sensitive coral reef resources, to implement water quality protection policies based on good science and a precautionary management framework. Such an approach will be required if the impacts of the escalating trend of nutrient enrichment to coastal systems is to be moderated. It remains to be seen if "adaptive management" can be introduced to the ongoing and expensive ($ 7.8 billion) "Everglades Restoration" plan. Indeed, it would be novel to recognize and manage for downstream impacts of land-based nitrogen enrichment in South Florida – a problem recognized by oceanographers over 100 years ago (Brandt 1899).

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THE HEALTH OF THE RIO DE LA PLATA SYSTEM, NORTHERN COAST, URUGUAY

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Abstract

We review here some biogeochemical aspects of the Río de la Plata system in order to analyse health changes of the ecosystem. Riverine nutrient load was estimated to be 3.5 10^6 mol d^{-1} for DIP and 64 10^6 mol d^{-1} for DIN, accounting for about 75 % of total load and the remainder is from Buenos Aires city discharges. The tidal river region is nutrient-rich (DIN = 30-50 mmoles m^{-3}, DIP = 1.5-2.0 mmoles m^{-3}, N/P > 25, Si = 150-180 mmoles l^{-1}) and cyanobactaria blooms have increased in the last 20 years. The estuarine region is stratified, plankton-dominated and autotrophic. Long term studies show an increase of river flow (> 30 %, 1940-1990) leading to a decrease of salinity (-3 psu, 1940-1990), an increase of stratification and extended oxygen stress (< 60 % saturation in the bottom layer) with hypoxic events (< 20 %). Part of this variability is ENSO related. Moreover, nutrient levels of 2.0-3.0 mmol m^{-3} for DIN and 0.7-0.8 mmol m^{-3} for DIP at 15 psu, indicates strong DIN sink (-60 %), a half of which is due to denitrification (-1.3 mole m^{-2} y^{-1}) associated to oxygen stress. Phytoplankton biomass is mostly in the range 2-15 mg m^{-3} and harmful blooms became frequent in the last 20 years. The Montevideo bay is an eutrophicated subsystem due to effluents of sewage (ammonium = 20-130 mmoles m^{-3} , chlorophyll > 100 mg m^{-3}). Also, significant amount of heavy metals were found (Pb = 44-128 mg kg^{-1}, Cr = 79-253 mg kg^{-1}). These characteristics suggest that the environmental health of the Río de la Plata Northern coast is declining.

Key words: Río de la Plata, estuarine region, northern coast, environmental health, eutrophication.

Introduction

The Río de la Plata is located at about 35° S on the Atlantic coast of South America, being the second largest basin in Latin America (over 3.1 10^6 km^2). Two major harbours and cities, Buenos Aires (Argentina) and Montevideo (Uruguay) are located on its shore (Fig. 1).

The Río de la Plata is the widest river and estuarine system in the world (from 35 to 230 km), with dynamical conditions remarkable different from most other estuaries. Although several recent studies have covered many aspects of this system (Wells and Daborn 1997; Guerrero *et al.* 1997; Danulat *et al.* 1998; Piccolo and Perillo 1999; López Laborde and Nagy 1999; Framiñán *et al.* 1999;

López Laborde *et al.* 2000b; Muniz *et al.* 2000; Nagy 2000) there is still much work to be done to reach a basic understanding of its geomorphologic, dynamics and biological characteristics.

Research in the Río de la Plata is difficult and expensive because of its great geographic extent. A large number of observartions are needed to obtain a synoptic description of the estuary and to solve the spatial and temporal variability. The goal of this review is actually to show the state of the knowledge about the health of the northern coast of the Río de la Plata, where several fish species find refuge temporarily, for the purpose of reproduction, especially in the subestuaries and around the salinity and turbidity fronts.

Description of the study area

Morphology

The Río de la Plata covers an area of 38 10^3 km^2, 60 % of which is placed seaward of the mean salt intrusion limit. Depth ranges between 2 and 25 m. For the purpose of this study, and according to Ottmann and Urien (1965) and López Laborde and Nagy (1999), the Río de la Plata may be divided in several morphological regions (Fig. 1):

i. The upper region, with fluvial characteristics and affected by tides (tidal river).
ii. An intermediate region characterized by several shallow banks and estuarine fronts (estuarine region).
iii. The wide outer region with typical marine features (outer region).
iv. The Canal Oriental, a river palaeovalley at the northern coast.

Climatology

The general atmospheric circulation over the Río de la Plata area is controlled by a quasi-permanent South Atlantic high pressure system and the continuous passage of low presure systems that comes from the south (Taljaard 1967). Its typical weather evolution is controlled by:

i. The passage of polar air masses that changes wind directions from North to South, generating strong wind gusts and rainy events. When they reach Brazil their movement is reduced and the air is warmed, and later return to the South originating northerly winds; this stop when a new polar air mass begins to advance from the Patagonian region to the North.
ii. The interaction of frontal systems with subtropical air masses that produces cyclogenesis resulting in strong southeastern winds ("sudestada") over 30 m s^{-1} in extreme events, with storms and heavy rains for several days, causing urban flooding.
iii. A marked seasonal variability with predominance of eastern and southestern winds in spring and summer, and northwestern winds in fall and winter.

Tributary river discharge

The freshwater inflow is by the Paraná (75 %) and Uruguay Rivers and it typically varies between 22,000 and 28,000 $m^3 s^{-1}$, with extreme values during El Niño, *i.e.* more than 30,000 $m^3 s^{-1}$ and La Niña, *i.e.* less than 20,000 $m^3 s^{-1}$ (Nagy *et al.*, in prep.). The minimun usually occurs in January and maxima in March-April, June and September-October. A hydroclimatic shift occurred in the Río de la Plata basin in the the early seventies (García and Vargas 1998) and runoff fluctuations and trend increased about 30 % partly associated to ENSO-related variability (Nagy *et al.* 1997).

Tides

Tide is of the semidiurnal type with diurnal inequalities (Balay 1961). Tidal current velocities (predominantly ebb oriented because of tidal asymetry) are about 0.05 to 0.1 m s^{-1} at the northern coast (C.A.R.P 1990).

Much larger variations in sea level are induced by wind forcing. Over weather time-scale southeastern winds blowing along the main estuary axis often produce the "pilling-up" increase of tidal river and estuarine waters level (Fig. 2) about one or two meters during 48-72 h (Balay 1961; López Laborde *et al.* 1996, 2000a).

Salinity and stratification

Wind and river discharge control the seasonal variability of the salinity field in the upper layer, and diluted shelf waters occupy the bottom layer (Guerrero *et al.* 1997). During fall-winter the lowest wind influence and a maximum in river runoff result in a lower salinity regime; whereas during spring-summer, prevailing onshore winds and a minimum of riverine runoff induce a higher salinity condition.

According to the classification of Hansen and Rattray (1966) the prevailing stratification-circulation pattern is "Type 2b". In the Canal Oriental "Type 4" (salt wedge-highly stratified) is often found (López Laborde *et al.* 1996; López Laborde and Nagy 1999).

The mean upstream limit of the saline intrusion (0.5 psu) is located at (Fig. 3):

i. 120 km from the mouth during high river flow and offshore prevailing winds (*i.e.* January).
ii. 80 km from the mouth during high river flow (*i.e.* July or October).

The increment of river discharge decreased surface salinity (-3 psu, 1940-1990) and promoted higher stratification.

Turbidity

One of the main features of the Río de la Plata is a marked estuarine turbidity front (ETF) located on the average close to the 5 m isobath ("Barra del Indio"), and associated with low salinities (Framiñán and Brown 1996; Nagy *et al.* 1997). Secchi disk measurements within this frontal region sharply increase with salinity (0.1-5) at a quasi-linear trend from 0.2 to 1 m, corresponding to a decrease of turbidity from ~ 100 to 10 NTU. Seaward transparency increases up to 4-6 m (Nagy *et al.* 1997).

An estuarine turbidity maximum (ETM) related to gravitational circulation and clay particles floculation develops at the transitional "null zone" between the tidal river and estuarine region (Nagy *et al.* 1987; López Laborde and Nagy 1999). The ETM is usually associated with the salt intrusion limit (0.5 psu). Suspended matter reaches 0.6-0.8 g l^{-1} or more near the bottom at the ETM, and the typical range is 0.1-0.4 g l^{-1} (López Laborde and Nagy 1999).

Framiñán and Brown (1996) studied the mean spatial distribution and the seasonality of the ETF, based on satellite images, showing that the turbidity front has a higher degree of variability at the northern coast. This is because of both wind forcing and high Uruguay river variability.

Temperature

Water temperature varies between 8 and 27.4 °C. The mean temperature field remains almost homogeneous for the warm (December-March) and cold (June-September) periods, both in vertical and horizontal scales (Guerrero *et al.* 1997).

Water quality, nutrient standing stock, and eutrophication

Sources

Diffuse sources of nutrients are the main input of nitrates, especially during floods, whereas point sources from Buenos Aires and Montevideo increase nitrates, ammonium and phosphates, reaching about 25 % of the total nutrient load to the system (Pizarro and Orlando 1984; Nagy *et al.*, in prep.). Nagy (2000) recalculated nutrient loads for the eighties as 3.5 10^6 mol DIP d^{-1} and 64 10^6 mol DIN d^{-1}.

Nutrients, particulate matter, and eutrophication

Available information on annual cycles of standing stock of biogenic matter of the Río de la Plata (Table 1) is limited to distribution of dissolved inorganic nitrogen (DIN), phosphorus (DIP), and silica (DRSi), a phytoplankton biomass indicator (chlorophyll *a*), and suspended particulate matter (SPM).

Short-term variability in nutrient concentrations occurs in the Canal Oriental due to changes in nutrient loading from wash-out drainage basins in response to extreme climate events.

The riverine and sewage inputs from the tidal river yielded up to 1-5 mM ammonium, 20-29 mM nitrate, 1.4-1.6 mM phosphate, and 160-180 mM silicate (Pizarro and Orlando 1984; C.A.R.P 1990; Nagy 2000).

Mixing diagrams for surface layer DIP, DIN and DRSi (Fig. 4) suggest that nutrients are removed by phytoplankton in the lower salinity region (< 15 psu) and partly released at bottom high salinities. This may be related, for the different nutrients, to remineralization, desorption, and *in situ* production in the benthic environment (Nagy *et al.*, in prep.).

DIN usually varies from 2 to10 mM and DIP varies from 0.3 to 1.5 mM. This corresponds to the range established for most of subtropical coastal zones with low cultural eutrophication (Nixon 1995). Greater values, *i.e.* 3 mM, typical of impacted estuaries, are sometimes found at the estuarine front region due to resuspension of remobilized DIP and DIN originated from both anthropogenic and *in situ* produced organic matter.

Symptoms of eutrophication in open waters far from point sources are (Méndez *et al.* 1996; Gómez-Erache *et al.* 2000a; Nagy 2000; Nagy *et al.*, in prep.):

i. High chlorophyll *a* values, *i.e.* 16 or 38 mg chl-*a* l^{-1}.
ii. Oxygen stress beneath the halocline after prolonged stratification, *i.e.* 10 or 40 % O_2 saturation.
iii. Increased ocurrence of harmful blooms.
iv. Some local high concentrations of nitrates, *i.e.* 40 mM, and phosphates, *i.e.* > 3 mM.
v. A positive net system metabolism during mixed conditions (7 mole m^{-2} y^{-1}) at the estuarine region.
vi. High denitrification rates (-1.3 mole m^{-2} y^{-1}) at the estuarine region.

The water quality of Montevideo Bay (34°35' S – 55°10' W) is highly deteriorated because of the several point and non-point sources and harbor activities. This subsystem is ~ 10 km^2, and most of its water comes from the Río de la Plata, with minor contribution from three little creeks and several sewage outlets heavily charged in heavy metals, nutrients and BOD. Two jetties protect the bay from southern strong winds. Waters outside the jetties behave like the Río de la Plata with the exception of the city sewage outfall zone.

The standing stock of particulates generally attains peak concentrations in the late summer and early fall, reflecting a trend towards a unimodal seasonal pattern in the development of autotrophic biomass, *i.e.* chlorophyll (Table 2).

Nutrient concentration may be clearly hypertrophic, *i.e.* in summer, with high concentrations of ammonium (up to 120 mM) and chlorophyll *a* (> 100 mg chl-*a* l^{-1}), and hypoxia (0-20 % of oxygen saturation) as a consequence of domestic effluent discharge and relatively high residence time.

Heavy metal concentrations, chromium and lead, were determined seasonally at five sites: harbour; inner, middle and outer Montevideo Bay and the adjacent Río de la Plata coastal zone (Table 2). All the values are the highest reported for the region compared with data presented by Lacerda *et al.* (1998). This is particularly true for chromium in the middle bay and for lead in the inner and middle bay. The origins of these metals are tanneries and gasoline combustion and paint industries, respectivel!y (Lacerda *et al.* 1998).

The balance of evidence, even if yet partial, suggests that the health of the Río de la Plata is declining due to both anthropogenic and natural causes.

Primary producers, harmful blooms and trophic state

Primary producers

The Río de la Plata is a phytoplankton-based system (Gómez-Erache *et al.* 2000a). Most of extensive blooms are dominated by micro-flagellates in the tidal river region, micro- flagellates and diatoms in the estuarine region, and centric diatoms and dinoflagellates in the coastal ocean region.

In the tidal river region it is possible to find extensive blooms of cyanobacteria (*Mycrocistis aureginosa*) in spring and summer originated since 1980 in the Salto Grande dam reservoir and reaching the Río de la Plata through the Uruguay River discharge (Gómez and De León 2000).

Harmful blooms

Successive episodes of coastal mussel toxicity have been reported since 1980 in Uruguay (Méndez 1993). Periodic plankton studies show that toxic outbreaks of *Gymnodinium catenatum* and *Alexandrium tamarense* occurred in summer and early spring, respectively (Méndez 1994). Nevertheless, between January 1991 and December 1994 six shellfish closures were imposed due to high PSP levels (Méndez *et al.*1996). This increment of toxic blooms during the last few years may be related with changes in environmental conditions. Méndez *et al.* (1996) suggest that development of *A. tamerensi* blooms are regulated by abnormal situations:

i. An increment of the strength and northward displacement of the Malvinas current, inducing a temperature range (11–15 °C) adequate for the development of *A. tamarense* blooms in early spring.

ii. A decrease of river discharge with the consequent inflow of marine water inducing high salinities (26-33 psu).

The authors only considered the Paraná River discharge. However, during early spring the contribution of the Uruguay River is usually high, controlling the northern coast hydrology (Nagy *et al.*, in prep.). Nevertheless, in 1991 and 1993 the Uruguay River flows were the lowest for September since 1980 allowing the increase of salinity in the coastal zone up to the values supposed to be ideal to develop *A. tamarense* blooms. In fact, a moderate bloom ocurred in September 1992 when the Uruguay river discharge was high because of El Niño event, with salinities between 9–22 psu within the study area. We conclude, in agreement with the authors, that the decrease of river discharge was a controlling factor, probably the main one, but mostly related to the low of Uruguay River flow. This is suggested by the fact that in 1991 and 1993 the northward displacement and frontal strength of the subtropical confluence were quite similar than in 1992 but the Uruguay River flow was higher. The bloom was moderate within the Río de la Plata (10-22 psu) and strong at the Atlantic coast where there was an adequate salinity range (> 26 psu).

Primary production

Primary production was measured for the first time in the Río de la Plata estuary in January 1999 along the Canal Oriental (Gómez-Erache *et al.* 2000a). The results show a high production rate measured in low turbid waters associated with a high-salinity mixed-water column. Nutrient concentration (N and Si) was relatively low, suggesting phytoplankton assimilation, but sufficient to sustain primary production. Primary productivity was to the same order of regional values reported by Abreu *et al.* 1992, supporting the hypothesis that the phytoplankton community of the Canal Oriental has a high assimilation number. The Río de la Plata system could be ranked within the meso-eutrophic coastal systems. Turbidity would not be a limiting factor for salinities greater than 3 psu and phytoplankton communities seem to be adapted to varying light availability.

Trophic state

Thus, in comparing systems, chlorophyll *a* remains the only useful, practical and simple measure of trophic state (TS) ranking (Golterman and Oude 1991). Comparative TS-ranking of highly diversified coastal systems requires that the systems first were grouped according to their physical, geomorphological, and biogeochemical characteristics. Based on mean annual chlorophyll stock, the TS-ranking system (Rast and Holland 1988) indicates that the tidal river and coastal ocean regions are mesoeutrophic. Despite the former high trophic state may be found close to the cities, the estuarine region is meso-eutrophic. Hypertrophism may occur in Montevideo Bay, *i.e.* in summer, as a result of high levels of mostly untreated urban and industrial nutrient loading, although usually for only short periods.

Human impact

The Uruguayan coastal zone is subjected to human impacts: shore erosion, local rise of relative sea level, uncontrolled land use and drainage basin fertilization, deforestation, El Niño floods, and urban-industrial expansion are of particular concern. It is being menaced by unplanned demographic expansion, and increased seawage discharge. Estimates of the increase of nutrient load due to population growth, from which to infer trends of eutrophication, have yet to be established (López Laborde *et al.* 2000b). Río de la Plata is affected by all these factors. The large size, wind mixing, and storage capacity of the estuary help to counteract some of these human impacts. Nevertheless, this is absolutely not true for the small Montevideo Bay which is heavely impacted by domestic effluent discharge and heavy metals (Danulat *et al.* 1998; Muniz *et al.* 2000).

Assuming that the main symptoms of eutrophication are nutrient over-enrichment, increase of primary production and biomass, secondary development of seasonally flagellates blooms, and potential hypoxia in stratification conditions, the Río de la Plata seems to go toward a eutrophied condition since 1980, due to both anthropogenic and natural causes.

Management issues

How best to manage the coastal zone does not have a simple solution, and the radical options that prevail are difficult to digest politically. The only reliable mitigation option is to reduce the nutrient load, primarily by both the management of watershed activities and sewage treatment.

In Uruguay, awareness by financial and management institutions of the need for environmental planning and clean-up is increasing. Reasonable management plans have been proposed by the Municipality of Montevideo, Montevideo Harbour Administration and Environmental Ministry. Also, the Ecoplata project promote recommendations to be taken into account in the elaboration of a Coastal Zone Management Plan. However, solutions still need to be implemented, and the precautionary principle is not yet widely applied in Uruguay.

In this sense, we propose the definition of management zones for the ecoregion of the Canal Oriental to define the use of its coastal and marine areas. The development of the methodology for the marine zoning includes three phases (Ferrán-Almada *et al.* 2000):

i. System classification, which define the elements to be applied (hydrodynamics, bathymetric features, sediment distribution, nutrient availability and primary production) and the integration sequence of these elements.
ii. Spatial distribution of the nutrient and primary productivity values for the area, hydrodynamic variability, and bathymetric features distribution.
iii. Overlapping, which integrates the elements producing environmental units.

Each one of these units represents a management area that could be used to define or evaluate specific management strategies. In order to define the management capacity of the system, each unit will be evaluated using the fragility, pressure and vulnerability indicators to establish the spatial distribution of the environmental policy for the ecoregion of the Canal Oriental.

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Table 1. Reported values of temperature, salinity, nitrate, phosphate, chlorophyll for the Rio de la Plata and marine plume (from Gómez *et al.* 2000).

SYSTEM	TEMPERATURE °C	SALINITY ups	N/NO_3 µM	P/PO_4 µM	Chlo *a* mg m^{-3}	REFERENCE
Tidal river 1992-95	5.2-27.8	1.2-17.7	0.1-1.1	0.2-0.4	<2.0-12.3	AGOSBA-OSN-SIHN 1997
Estuarine Winter	n.a.	n.a.	n.a.	n.a.	<0.2-1.4	Bazigaluz 1981
Estuarine 1981-87	9.5-22.7	0.1-25.8	59-112	0.03-1.7	0.4-7.0	CARP 1989
Estuarine Spring	21.0-23.0	6-20	n.a.	n.a.	2-13	Gómez *et al.* 1996
Estuarine 1997-98	12.0-24.0	0.2-16.0	n.a.	n.a.	0.6-143	Gómez *et al.* 1998
Marine Summer	n.a.	n.a.	n.a.	n.a.	0.2-3.0	Texeira *et al.* 1973
Marine Fall	n.a.	n.a.	n.a.	n.a.	25.0	Texeira *et al.* 1973
Marine Fall	6.8-24.5	28.2-37.1	0.03-18.4	0.3	1.3	Hubold 1980 a,b
MarineEarly Spring	6.8-24.5	28.2-37.1	0-18.4	0.31	0.38	Hubold 1980 a,b
Marine Spring	15.0-16.0	15.0-25.0	n.a.	0.7	0.2-12.5	Carreto *et al.* 1983
Marine Summer	n.a.	n.a.	n.a.	n.a.	4.1-9.5	Vasconcellos 1982
Marine Fall	n.a.	n.a.	n.a.	n.a.	2.9-7.8	Vasconcellos 1982
MarineSpring	13.0-16.0	0-33.0	10	0.4-0.70	3.0-7.7	Carreto *et al.* 1986
Marine Summer	n.a.	n.a.	n.a.	n.a.	0.4-7.9	Parietti 1986
Marine Summer	12.5-24.0	20.0-29.0	0.04-1.91	0.12-1.72	4.9-69	Milstein 1985
Marine Winter	10.0-11.0	31.0-33.0	n.a.	n.a.	1.0-33.0	Bayssé *et al.* 1986
Marine Summer	17.2-23.7	28.5-34.6	n.a.	n.a.	0.1-4.1	Mesones 1991
Marine Fall	n.a.	n.a.	n.a.	n.a.	3.4-98.1	Gonzalez 1994

Table 2. Heavy metal concentrations, minimum and maximum values reported in bottom sediments (mg g^{-1} d.w.) from Montevideo Bay Harbour and adjacent coastal zone of the Rio de la Plata. The values are compared with subrecent Rhine and Southern California coastal zone river sediments.

LOCATION	Cr µg g^{-1}	Pb µg g^{-1}	Reference
MONTEVIDEO BAY			
Harbour	84-86	68-189	Danulat *et al.* 1998
Inner	68-189	109-350	Muniz *et al.* 2000
Middle	265-1062	99-365	Muniz *et al.* 2000
Outer	21-45	10-54	Muniz *et al.* 2000
Adjacent Coast	37-40	38-56	Muniz *et al.* 2000
CARRASCO CREEK	10-807	17-73	Lacerda *et al.* 1998
BAHIA BLANCA, ARGENTINA 39°S	n.a	13-17	Villa 1998
PATOS LAGOON, BRAZIL 32°S	8-337	8-267	Baisch 1988
RHINE RIVER, GERMANY	47	30	Novotny 1995
SOUTH CALIFORNIA COAST	2.5	4.5	Thompson *et al.* 1987

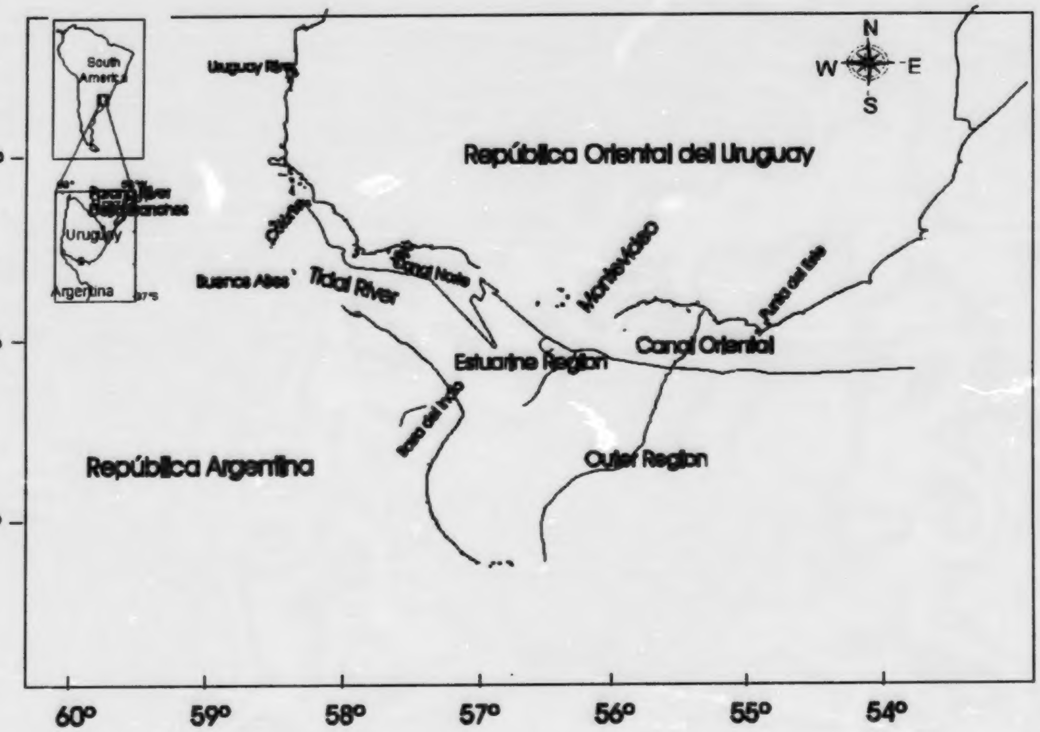
South America
Uruguay
Argentina
Uruguay River
N
W
E
S
República Oriental del Uruguay
Buenos Aires
Tidal River
Canal Norte
Montevideo
Punta del Este
Estuarine Region
Canal Oriental
Barra del Indio
Outer Region
República Argentina
34°
35°
36°
60°
59°
58°
57°
56°
55°
54°

Figure 1. Rio de la Plata hydromorphological units and regions (modified from Lopez Laborde and Nagy 1999).

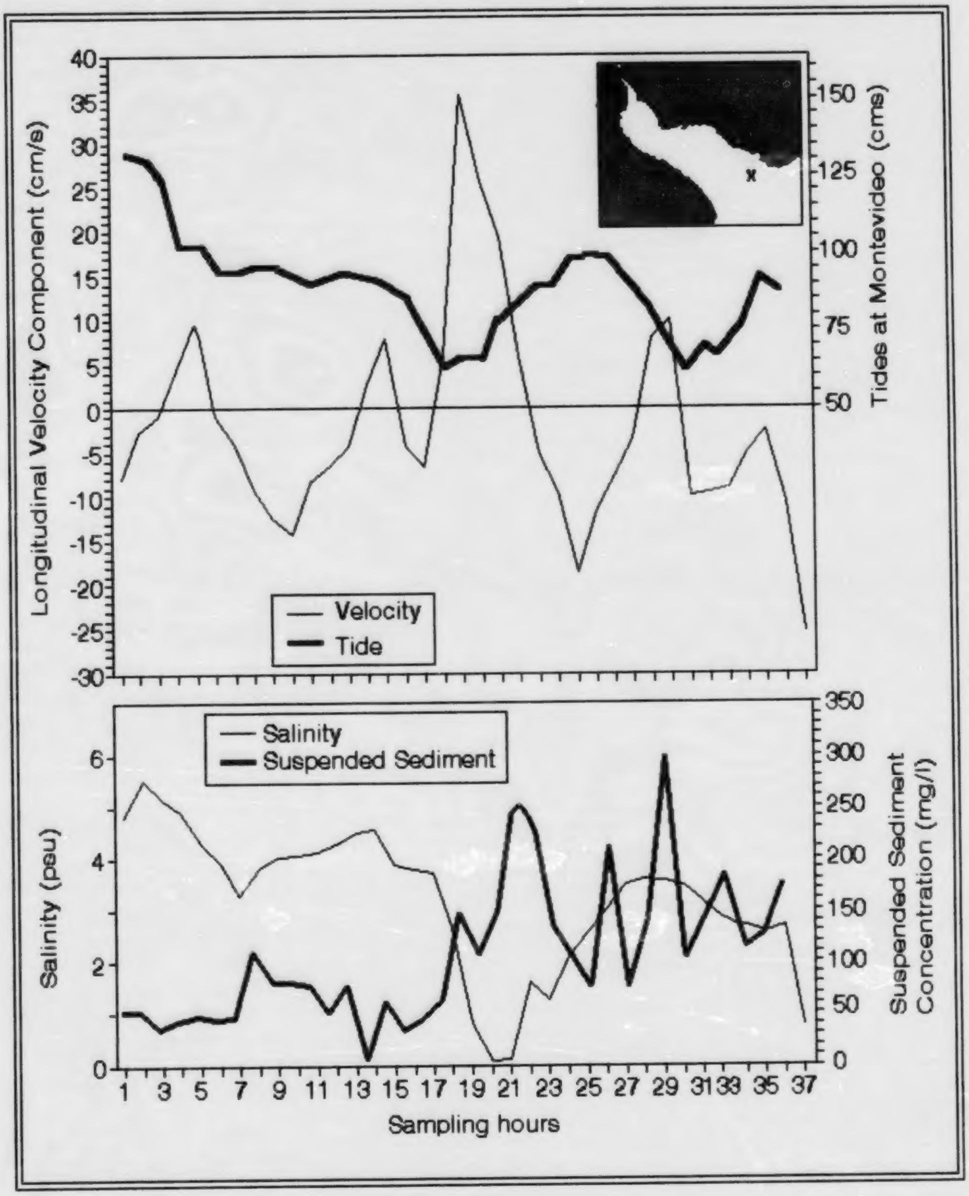

Figure 2. Tides (cm), longitudinal velocity component (cm s^{-1}), salinity (psu) and suspended sediment concentration (mg l^{-1}) at one metre above the bottom, during an anchored station in the Canal Oriental (35°06'48''S to 56°34'18''W) (from López Laborde and Nagy 1999).

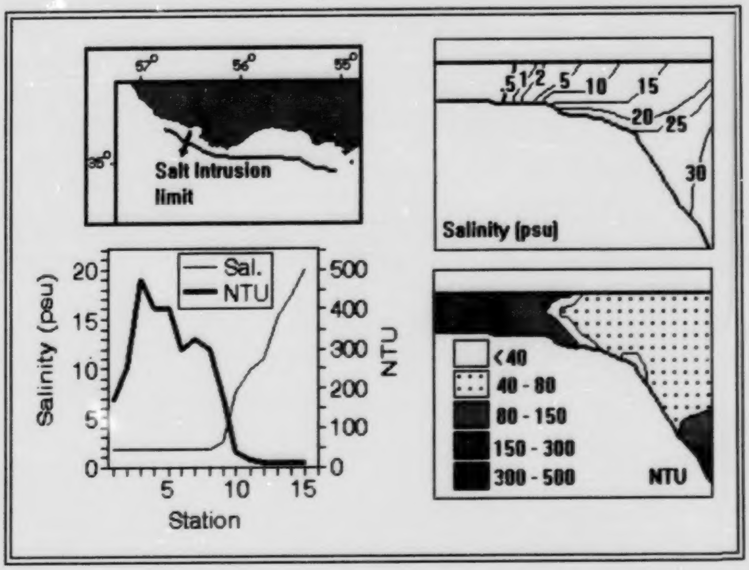

Figure 3. Salt intrusion limit, stratification patterns, and turbidity maximum in the Canal Oriental (from López Laborde and Nagy 1999).

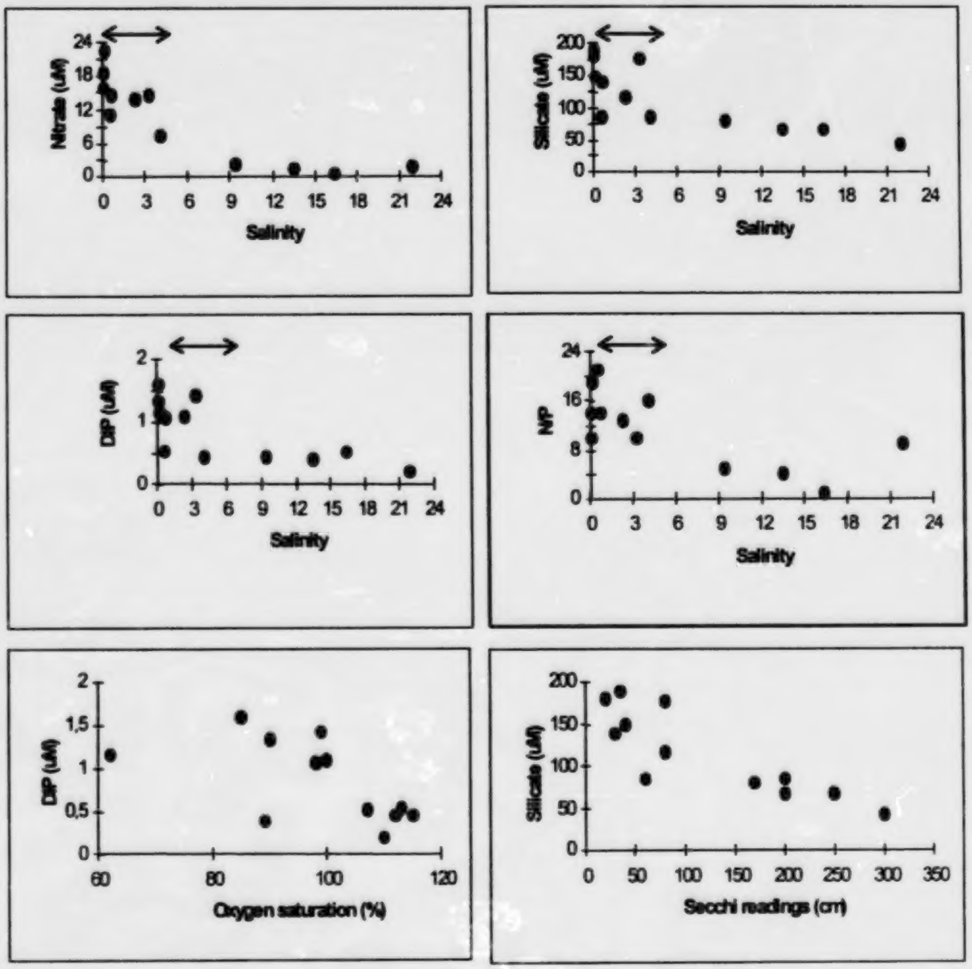

Figure 4. Typical mixing diagrams (nitrate, silicate, DIP and N/P) for the northern coast of Río de la Plata. Oxygen saturation and Secchi disk readings suggest biological removal of nutrients. The arrows show the maximum nutrient sink interval (modified from Nagy *et al.* 1997).

NUTRIENT DYNAMICS IN INLETS IN THE MARITIMES

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A wide variety of inlet shapes, sizes, and types are found along the highly indented coastlines of the Maritime provinces of Canada. Some inlets are shallow barachois environments; many others are relatively open to the sea. Some inlets are fjords with isolated deep basins whose water is only replaced episodically. Circulation in some inlets is dominated by river inputs; in others, by wind and offshore forcing, and in others by some of the highest tides in the world. These widely varying conditions lead to equally diverse behaviour of nutrients in the inlets in the Maritimes.

We have conducted a number of case studies on nutrient dynamics in the region, including ones in Ship Harbour (a small fjord on Nova Scotia's Atlantic coast), the Letang Inlet (a macrotidal inlet on the Bay of Fundy), the Kouchibouguac estuary (a river dominated barachois on New Brunswick's Gulf of St. Lawrence shore), and the Bras d'Or Lakes (a group of interconnecting, saltwater basins on Cape Breton Island). We have also examined ways of predicting the eutrophication status of inlets in the region. This talk will revisit these studies of nutrient behaviours to illustrate the variety of nutrient conditions found in the region, with a focus on the eutrophication status of the inlets, and their sensitivity to changes caused by increased inputs of nutrients.

AN OVERVIEW OF CIRCULATION AND MIXING IN THE BAY OF FUNDY AND ADJACENT AREAS

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How quickly is an area flushed or how quickly is a source of nutrients diluted? These are commonly asked questions of relevance to the issue of nutrient enrichment. An answer that is often given for the Bay of Fundy is that because of the high tides and strong tidal currents, the Bay is flushed rapidly and substances are diluted quickly. However, this is not always the case, and in order to answer the question appropriately one must consider aspects such as the rate and duration of input, the spatial scale of input, the rates and patterns of mixing and water transport as well as that of nutrient uptake. Some of the general concepts and perspectives pertaining to circulation and dispersion are briefly summarized below. These are followed by brief overviews of how these have been applied to the Bay of Fundy and the inshore area of southwestern New Brunswick. The rates of nutrient input and uptake are not considered.

General Concepts

One perspective that is useful when considering what happens to a source of nutrients released into a body of water is that of advection and dispersion. Advection is the translation of a water parcel over time and dispersion is the spreading out of this parcel due to processes such as turbulent diffusion and shear dispersion. In the Bay of Fundy the initial rate and direction of advection is dominated by the lunar tide. The tide tends to move substances back and forth on a time scale of 12.42 hours. The distance covered from one extreme location to another during a single tidal cycle is referred to as the tidal excursion. Over time periods of several tidal cycles, a net speed and direction of translocation results. This is referred to as the mean or residual flow and it varies on time scales of days, weeks, months and years. During the advection processes, a patch of water is also spreading out and becoming more dilute. It is dispersing and being mixed with other components of the water. The rate of this mixing increases with the size of the dispersing patch.

The rates of advection (V) and dispersion (K) have been estimated by methods such as the release of drifters and dye, the mooring of current meters, the measurement of hydrographic conditions and the development of circulation and mixing models. Estimates of the time required to advect or disperse a given distance (L) can be calculated as $T_{adv}=L/V$ and $T_{disp}=L^2/K$, respectively.

A second perspective that can sometimes be useful is to focus on a specific volume or box of water. In this approach it is assumed each parcel of water introduced into the box is rapidly and evenly mixed throughout the box and that water leaving the box does not return. These assumptions are often not satisfied and hence the approach should be used cautiously. It is also generally assumed that the rates of water entering and leaving the box are equal so that the volume of water in the box does not change on the time unit of interest. A commonly calculated value is the proportion of the water within the box that is removed during each unit of time. This is called the exchange ratio and in the Bay of Fundy the unit of time is usually a tidal cycle. The inverse of this is the flushing or residence time, which is the time for 65 % of the water in the box to be removed. This is also referred to as the e-folding time. The exchange ration can be estimated in various ways. One common method is to calculate the ratio of the amount of water entering a box during flood tide to the volume of water within the box at high tide. This is the tidal prism method. Another approach, the salt budget, estimates the amount of fresh water in the box from measurements of salinity and relates this to the rate of freshwater inflow measured or estimated for nearby rivers. A third approach is to use a circulation model to track the disappearance of a substance from a specified area.

These perspectives and methods have all been applied to the Bay of Fundy and the inshore area of southwestern New Brunswick.

Circulation and mixing within the Bay of Fundy

Circulation within the Bay of Fundy has been summarized by many authors including an early and insightful review by Watson (1936). Water circulation within the Bay of Fundy is dominated by the lunar tide. The tidal current flows into and out of the bay every 12.42 hours at velocities of about $10 cm \cdot s^{-1}$. The mean or residual circulation has near the surface water entering the Bay along the coast of Nova Scotia and at depth through the deep entrance between Grand Manan and Nova Scotia. The water begins to cross the Bay along a line from Digby, Nova Scotia to Saint John, New Brunswick and leaves on the New Brunswick side of the Bay. The residual circulation is driven in part by the freshwater input from the Saint John River which contributes to the New Brunswick side of the Bay being vertically stratified. Typical residual velocities are 5-9km/d. Hence, it takes about 5-6 days to advect from near Saint John to past Grand Manan, a distance of about 50 kilometers.

Flushing rates for cross-sections of the bay have been estimated by Ketchum and Keen (1953). Mixing rates for the inner Bay of Fundy, the part of the Bay eastward of the line joining Digby and Saint John, have been estimated by Holloway (1981). Both analyses relied on measurements of salinity and freshwater input. Although flushing rates for individual sections were estimated to be only a few days, the flushing time for the Bay as a whole was estimated to be about 76 days, much longer than the time to advect out of the Bay in the surface layer. This estimate is however modified to an unknown extent by the vertical stratification and horizontal variations in the residual flow. The horizontal rate of dispersion for the upper bay was estimated to increase from Minas Basin toward the outer bay with a typical value near the head of the Bay being $100 m^2 \cdot s^{-1}$.

Circulation and mixing within Southwestern New Brunswick

As in the Bay of Fundy as a whole, water circulation in the southwestern New Brunswick area is dominated by the lunar tide. The tidal velocities vary considerably on short spatial scales and magnitudes range from near 0 $cm \cdot s^{-1}$ to several 100 $cm \cdot s^{-1}$. The residual velocities vary seasonally with changes in winds and freshwater runoff. The magnitudes of these velocities are not well known.

Flushing times for the region have been estimated from considerations of salinity and freshwater input by Ketchum and Keen (1953), from tidal prism calculations made from data in Trites and Petrie (1995) and from a circulation model described by (Trites and Petrie 1995). For example, the flushing time estimate for Passamaquoddy Bay is 16 days and that for Lime Kiln Bay is about 2 days. Recent circulation modeling and particle tracking efforts by D. Greenberg (DFO/BIO), M. Dowd (DFO/SABS), K. Thompson (Dalhousie University) and others (pers. comm.) using Greenberg's 3D finite element tidal model (Greenberg *et al.* 1997) simulates the process of advective-stirring by the tides.

Discussion

Despite the fact that a considerable amount of effort over the past 100 years has been directed toward understanding the patterns and rates of circulation and mixing within the Bay of Fundy, much still needs to be done. Although existing flushing estimates are crude, they do suggest that the Bay and some of the inshore coves and inlets may not be flushed as quickly as perhaps imagined by some. Most of the effort has been directed at tidal phenomena because of the large tidal range within the Bay and the periodic interest in tidal power. Relatively little effort has been focused on other aspects of the circulation. Because of the complex bathymetry in some areas, such as southwestern New Brunswick, the circulation and flushing patterns vary on small space and time scales. This makes it difficult and sometimes inappropriate to make or apply generalizations. Hopefully, with some of the renewed interest and research activity in the area, a better understanding of the circulation and mixing dynamics will begin to emerge and be made available for addressing issues of relevance to coastal zone management, including that of nutrification and eutrophication.

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THE ROLE OF SEAWEEDS IN INTEGRATED AQUACULTURE AND THEIR CONTRIBUTION TO NUTRIENT BIOREMEDIATION OF COASTAL WATERS

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Impact studies on aquaculture operations have generally focused on organic matter/sludge deposition. However, as nutrification of coastal waters becomes a pressing worldwide issue, the contribution of the inorganic output of aquaculture to significant nutrient loading has become more widely recognized. Several national and international agencies/organizations, charged with environmental protection and coastal management, are presently developing guidelines and codes of practice for sustainable management of aquaculture activities. It is, however, striking to realize that most often aquaculture remains monospecific and of the "fed" (finfish) type. For a balanced ecosystem approach, "extractive" (shellfish and seaweeds) aquaculture should be an integrated component of any new approach to innovative aquaculture development. Unfortunately, the fundamental role and contribution of seaweeds has often been either ignored or misunderstood, especially in the Western world, and is rarely factored into modeling equations of coastal budgets. Seaweeds not only can act as renewable biological nutrient scrubbers for water quality enhancement/coastal health improvement, but also represent marine crops of commercial value. The concepts of bioremediation, mutual benefits for the co-cultured organisms, and economic diversification of the aquaculture industry, will be discussed and illustrated by the results of the projects we are conducting in the Maritime Provinces, Canada, and in New England, USA.

Session Two

TIDAL POWER DEVELOPMENT - ENVIRONMENTAL ISSUES AND CONSTRAINTS

Chair: Ken Sollows, University of New Brunswick,
Saint John, New Brunswick

INTRODUCTION AND OVERVIEW OF THE ENVIRONMENTAL AND ECONOMIC IMPACTS OF NON-TIDAL ENERGY TECHNOLOGIES

K.F. Sollows

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The environmental and economic impacts of non-tidal energy technologies will be reviewed. Various alternative technologies will be considered, including fossil-fueled, non-tidal hydroelectric, nuclear, biomass, solar, wind, and conservation. The advantages and disadvantages of the quantified external cost approach to integrating environmental and economic costs will be reviewed.

The goal of the presentation is to create a context for consideration of Fundy tidal power along with those technologies it may replace/augment. This environmental/economic context will hopefully lead individual participants to make a balanced assessment of environmental risks in their deliberations.

The overall goal for the afternoon's sessions will be to develop a consensus statement on the environmental concerns, considerations and/or conditions that should be satisfied by any plans for Fundy tidal power development.

REVIEW OF ENGINEERING STUDIES ON TIDAL POWER, TECHNICAL/ECONOMIC PERFORMANCE OF EXISTING PLANTS, AND SCENARIO FOR THE BAY OF FUNDY

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A summary of the series of Fundy tidal power studies, conducted from 1966 to 1988, will be presented. The performance of existing plants will be reviewed, including the La Rance tidal power project that has operated in France (since 1966) and the Annapolis tidal power project in Nova Scotia (since 1985). The nature and extent of power plant structures for various development options will be described. The goal of the presentation is to inform the group regarding the engineering and economic characteristics of tidal power options.

TIDAL POWER DEVELOPMENT - ENVIRONMENTAL ISSUES AND CONSTRAINTS

G. Daborn and M. Dadswell

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Previous investigations of tidal power proposals in the Bay of Fundy region indicated significant environmental concerns associated with: changes to tidal range; sedimentation processes; potential for eutrophication; effects on migratory birds, fish and mammals; and poorly-predictable effects on fishery resources. Many of these concerns were associated with the design and physical nature of the dam built to retain tidal water and to house the turbines. Recent proposals for tidal power development in macrotidal estuaries in other countries have used similar designs and anticipated similar profound environmental effects. This presentation will outline the state of environmental knowledge in the Fundy region, and lay a foundation for considering the consequences of new proposals.

TIDAL POWER DEVELOPMENT - ENVIRONMENTAL ISSUES AND CONSTRAINTS
Summary of the Workshop

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The workshop began with the finding of the 1977 study of Fundy Tidal Power:

> "Environmental considerations are unlikely to be of sufficient importance to affect a decision to proceed with development of a tidal power project or to result in a strong preference for any site."
> - Finding 17.9, Management Committee Report, 1977

The focus of the afternoon's work was to be reconsideration of this finding, in light of the results of work in and around the Bay of Fundy since that report. The environmental consequences of electricity production in the Maritime region were illustrated with the case of New Brunswick, in which 50 % of generation was derived from fossil fuels. The carbon dioxide and sulfur dioxide emissions associated with these sources were described. The presentation continued with a short description of conventional and unconventional alternatives to supplant such fossil fuel use, with emphasis on the potential negative consequences of such alternatives, to create an appropriate context for consideration of the issue.

The engineering characteristics of existing and planned tidal power plants were then described. The plant in Brittany, France, on the La Rance river estuary was commissioned in 1966 and equipped with 24 "Bulb" turbine-generators, each with a rated capacity of 10 MW. The propeller-type turbine has a diameter of 5.35 m. On the basin-side of and close to the turbine is a set of "wicket gates", an assembly of 18 adjustable vanes, spaced radially around the bulb. The Annapolis plant was commissioned in 1984 and is equipped with one "Straflo" turbine-generator with a rated capacity of 20 MW. The machine at Annapolis is larger than those at the La Rance plant. Its turbine diameter is 7.6 m and is similarly equipped with wicket gates. The turbine-generator machinery installed in these two plants, possibly with improvements to make them more environmental friendly, represent the presumed technology of choice for future tidal power plants, from an engineering perspective.

From an environmental perspective, the Bulb- and Straflo-types are similar in that the machine-water interfaces are similar. Both are horizontal axis machines that induce considerable swirl in the discharge flow. They both rely on impoundment to build up a significant head of water across the turbine and both exhibit rotor tip or rim velocities that are significantly higher than water velocities that fish normally encounter. In each case wicket gates are used to direct the flow of water over the moving blades to control energy production, creating a difficult path for fish passage.

The nature of the intertidal environment at potential tidal power sites in the upper Bay of Fundy was described. The extensive mud flats that are uncovered at low tides are important feeding areas for migratory birds that winter in South America. The nature of the mud flat ecosystem was described, highlighting the strong interaction between biological and geophysical processes.

Siltation processes that result from causeway construction in the upper Bay of Fundy were also described and contrasted. In the case of the causeway at Annapolis Royal, net erosion has occurred downstream of the structure, unearthing works that have lain buried for hundreds of years. In contrast, the causeway across the Avon river at Windsor has resulted in massive silt deposition downstream of the structure, threatening navigation and tending to the establishment of extensive salt marsh areas.

The effect of tidal power development on several fish species was also considered. The upper reaches of the Bay of Fundy are important areas for many species of fish, some of which migrate over large portions of the western Atlantic. Sizes range from relatively small fish such as herring, to sturgeon of 3 to 4 m in length. The area also provides important habitat for whales, unlike the test site at Annapolis Royal where no interaction with whales has been reported. The economic importance of the fisheries resources in the Bay of Fundy was stressed, as was the importance of the ecosystem's integrity for migratory species of fish that are exploited elsewhere.

The nature of fish movements in a tidal regime were described. Many species follow the tides in and out of an area for days or weeks at a time. Such populations would be especially vulnerable to mortality induced by turbine passage, in comparison with fresh water migratory species that might pass only once through a hydraulic turbine after spawning. The multiple passages make it necessary to either exclude such fish from the turbine, or reduce the probability of injury to a very low level.

The experience with fish mortality at the Annapolis Tidal Power project was described. Only a very small fraction of the fish passing through the facility make use of the fishway. Studies with shad indicate that a large proportion of the fish passing through the turbine are injured or killed, and population studies have shown a statistically significant decrease average fish size since the turbine commenced operation. The mechanism of mortality varies. Smaller species are likely to have swim bladders ruptured as they pass through the pressure drop that necessarily occurs with these types of machines. Larger fish are more likely to impact the fast moving blades or stationary obstructions as they try to negotiate passage.

Potential engineering responses to the significant environmental challenges of large-scale tidal power development were then discussed. Original development plans in Minas Basin (site B9) called for a single basin, impounding water at high tide and running the water through a constant speed turbine as the tide falls. Such operation would cut the basin's tidal range in half, reducing it from 12 m to 6 m and eliminating large areas of environmentally important mud flats. In addition, this was expected to change the tidal regime throughout the Gulf of Maine, increasing the tidal range at Boston by 30 cm. The original plan provided a relatively large head for the hydraulic machine. This is advantageous for energy production but it also increases the size of the pressure drop experienced by fish during passage and would thus lead to high mortality.

One large-scale alternative that gives consideration to these issues would be a tidal power plant constructed with much greater permeability. This could be achieved by increasing the number of turbines and operating them to produce energy on both the flooding and ebbing tides. This would result in a tidal range in the basin of 9 or 10 m, preserving larger areas of mud flats. Current technology would also support the use of variable speed turbines, which would reduce the obstructions to fish passage by allowing removal of the wicket gates. Such a configuration would also reduce the head across the turbines by 30 to 40 %, reducing the magnitude of the pressure fluctuation exposure by a similar amount. Such a plant configuration would also be expected to reduce siltation problems, since the flow regime more closely follows that of the undeveloped site. The same principles could be applied to other sites in the Bay of Fundy. The specific characteristics of each site would have to be considered, and such considerations may lead to other alternative configurations.

There was a general consensus that the finding of the 1977 report – that environmental effects would not be a significant factor in the decision to build a tidal power plant – no longer stands. The potential impacts on migratory birds, marine fish and mammals, and salt marsh habitat are all now recognized as significant and serious.

While the experience at the Annapolis Tidal Power plant offers little information on siltation or bird habitat reduction at other potential sites, it has clearly demonstrated problems of high fish mortality. The economic importance of the fisheries in the Bay of Fundy - Gulf of Maine region is such that fish mortality must be reduced to acceptable levels in any further developments. Indeed, further serious consideration should be given to measures to reduce fish mortality at the Anapolis plant. Such measures could range from techniques to increase fish passage through the fishways, to operational changes that limit energy production at certain times to allow safe passage of fish, to design changes (ranging up to and including the installation of alternative turbine technology) that might be implemented at a future refit of the plant.

With respect to siltation, there was general agreement that lessons are to be learned from the experience of the Maritime Marshland Rehabilitation Administration in renewing and extending dykes to preserve and claim agricultural land from the sea. Current efforts to remove dykes to reestablish salt marshes should be supported by careful prediction and analysis, to enhance our ability to predict the effects of future human interventions in the coastal environment.

There was considerable concern expressed that the scale of energy development generally – and tidal energy in particular – should be small enough to allow plans and actions to change in response to environmental lessons learned. This argues against large scale development of tidal power in the near future.

Within the constraint of small scale development, support was expressed for the continued development of techniques and technologies that facilitate the exploitation of tidal power at low environmental impact. Clearly, the technology that was the basis of the 1970's study and that is demonstrated at the Annapolis Tidal Power Project has demonstrated significant environmental drawbacks that were not anticipated. Technological advances that facilitate variable speed operation of low head machines hold some promise for reduced environmental impact and alternatives to the conventional design and operation of tidal power plants should be considered.

Session Three

ECOLOGICALLY AND COMMUNITY VALUED MARINE AREAS IN THE BAY OF FUNDY

(Criteria for MPA Site Identification and Selection)

Chairs: Maria-Ines Buzeta, Department of Fisheries and Oceans, St. Andrews, New Brunswick
Derek Fenton, Department of Fisheries and Oceans, Dartmouth, Nova Scotia

SESSION ABSTRACT

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Presently in the Bay of Fundy (BoF) a single "Area of Interest" (AOI), the Musquash estuary and salt marshes, has been officially identified within the Department of Fisheries and Oceans (DFO) Maritimes Marine Protected Area (MPA) Program. While Musquash provides an opportunity to test the Process, we still have to address the protection needs of other important and sensitive areas in the BoF. The ultimate goal of DFO is to develop a system of MPAs on behalf of the Government of Canada. Science, industry and the public have recommended a comprehensive scientific overview and a systematic review of the requirements for appropriate ecosystem management in the BoF. At the same time, there is a need to identify valued areas from available, scientific, social and traditional information, and to begin discussion on the protection needs of specific areas.

The identification of sites for future consideration can comprise an interim system plan consisting of areas that are of biological and social importance, giving priority to potentially threatened sites first. There are several sources of information and selection criteria used worldwide, and these must be reviewed for applicability within the BoF ecosystem. Not all sites will fit within a MPA system plan; some will require protection under other conservation legislation. But those that do should be reviewed by applying a set of criteria, along with a review process of ecological information, and through consultation with all interested parties.

This BoFEP 2000 roundtable discussion followed the Fundy Forum electronic discussion (February 7-21, 2000) on MPAs, and brought together participants with a variety of perspectives, providing a multidisciplinary discussion. It focused on achieving practical recommendations on how to build a "system plan": what tools, information, criteria and review process should be used for site identification, site selection, and prioritization of sites. Speakers provided background information as a resource for the subsequent discussion sessions, including information on: the objective of a network of MPAs; the use of selection criteria; the role of science in site selection and decision making; and the role of communities in identifying ecologically significant areas.

Posters contained background reference information: the use of mapping for a BoF ecological overview, and as a tool in decision making; a summary of the roundtable discussions on MPA system planning and the Fundy Forum discussions; an ecological overview of the Musquash ecology (a proposed MPA); and a sample of BoF biodiversity using underwater photographs. The discussion

sessions focused on specific questions useful in the development of a system of MPAs.

MPA INTRODUCTION AND DFO'S EFFORTS IN THE BAY OF FUNDY

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The *Oceans Act* was enacted in 1997, and consists of three parts; Part 2 contains the provisions for the Minister to lead and implement a national strategy for oceans management, based on the principles of sustainable development, integrated management and the precautionary approach. This section also provides some tools, including Marine Protected Areas (MPA). The definition of an MPA is *"an area of the sea that... has been designated for special protection"*. The reasons for designation are listed as conservation and protection of:

(a) commercial and non-commercial fisheries resources, including marine mammals and their habitat
(b) threatened or endangered marine mammals
(c) unique habitats
(d) areas of high biodiversity or biological productivity
(e) any other marine resource or habitat as is necessary to fulfill the Minister's mandate.

This means that MPAs could be used to protect critical habitats that act as a source of larval production, rare or threatened species and/or populations, to set aside representative areas for monitoring, study and research, to maintain ecosystem trophic structure, or to increase biomass of a target species and provide a "spill-over" of adults to exploited areas.

Why MPAs? They are proactive - protecting valued species and their habitats before degradation; they are precautionary - there is still a lot we do not understand and these areas can provide a baseline for monitoring and research; they contribute to a more ecosystem approach in the management of marine environment and resources - an important tool for integrated management; and they protect benthic habitats and maximize representation of species (biodiversity). Mark Costello (see below) expands on biodiversity.

The overall objective is to protect and conserve highly productive and important marine habitats and resources; to develop and implement an MPA program in partnership with communities, resource users, and federal, provincial and First Nations partners; and to develop a national network of MPAs. Bradley Barr (see below) gives more on marine protected areas systems from an international perspective.

The Musquash estuary in SW New Brunswick is located approximately 20 km west of the city of Saint John. The estuary and associated salt marshes are estimated at 1,656 ha. Musquash has been described by the Conservation Council of New Brunswick and others, as one of the last ecologically intact estuaries in the Bay of Fundy, and they, with the support of Fundy North Fishermen's Association, proposed it as an MPA. Janice Harvey (see below) expands on the community's role in designation. It was recently designated by DFO as an Area of Interest, an important step towards MPA designation. Since the initial proposal was submitted, DFO has contacted and met with all identified stakeholders, and formed The Musquash MPA Planning Group. The process has been open, and new interested parties are able to participate at any time. The original proposal has been reviewed and amended by this group, and will be part of the technical overview report. The overall objective "Protection and Restoration of the Musquash Estuary and surrounding Salt Marshes", was developed by the group, as have the individual goals for the proposed MPA. An ecological overview has been completed, and new research has been initiated on oceanography, contaminants, indicator species, benthic mapping and boundary definitions. This information will assist in reviewing its potential as an MPA, and for development of an appropriate management plan.

While Musquash provides an opportunity to test the Process, we still have to address the protection needs of other important and sensitive areas in the BoF. The ultimate goal of DFO is to develop a system of MPAs. An Ecosystem overview of the BoF, such as the one for Musquash, provides a quick summary of available information, and can be easily updated. It also identifies knowledge gaps, and what studies need to be initiated. Scientific information for evaluation of individual sites, and for development of a system of MPAs is not always available or adequate. There is a requirement not only for broad geographic information , but also for site specific intertidal and benthic ecology-mapping, benthic classification and structure, oceanography, nutrients and contaminants, species distribution- biodiversity, source-sink areas, and assessment of rare species.

If several available layers of information are overlapped, we can begin to see patterns that assist in making decisions, and assess which of these sites would provide and effective and reasonable system of MPAs, from an ecological perspective. While each site would be discussed independently with stakeholders they need to be put into perspective, on how expansive/or limited they might be, and of how (if they proceed) they would eventually fit into, or be nested within, an overall integrated management plan for the Bay of Fundy.

A summary of available information (Figure 1), not representing any official version of a system, but rather a composite representation of sites found in the literature (Table 1), or suggested by academics or non-governmental groups, show that many overlap/superimpose each other, warranting a closer look. These include areas considered significant, such as highly biodiverse areas or spawning areas, or community valued areas, or areas suggested by various groups as being significant enough to warrant looking at them as potential MPAS. Prominently identified is the Fundy Isles area, where several references have identified it as significant, and many small areas within have been described during consultations as being highly biodiverse. References and information listed in Table 1 requires further analysis. Consultation on sensitive areas continues, prior to any system planning, to ensure that input is obtained from a wide variety of stakeholders.

In contrast, the land based areas which are presently protected under various legislation along the coast, represent 200 sites for a total of over 110K hectares. Overall in NB-NS there are 718 of these sites, for a total of more than 465K hectares.

From previous discussions, I can summarize that we all recognize the need for thorough science, yet many feel that while we wait for information, there are fewer areas "available" for protection, as they become either degradated, or heavily utilized. The question always arises on the role of the Precautionary Approach and its role in site selection.

Results of the Fundy Forum electronic discussion (www.fundyforum.com/) show a nested approach may be reasonable for the BoF, whereby a network of small areas is managed together, using a community based approach. At the same time, protection of small pockets of ocean will not address all problems, nor be the only solution. There also has to a balance between commercial or economic interests, and the environmental interests and requirements. A network of small pockets can only begin to address this balance.

Ultimately, decisions will have to be made on where and how to identify and implement these MPAS. Not all sites initially identified will fit within a MPA system plan; some will require protection under other conservation legislation. But those that do should be reviewed by applying a set of criteria, along with a review process of ecological information, and through consultation with all interested parties. And this is why selection criteria, as summarized by Derek Fenton (see below), must be discussed so that they are suitable to BoF.

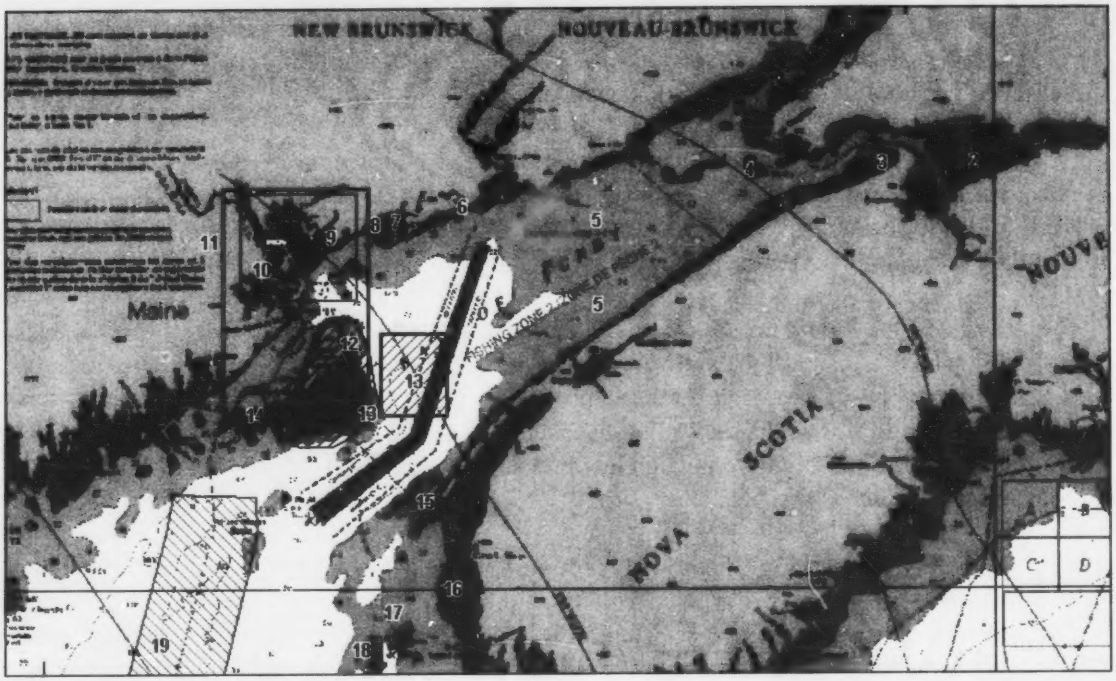
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Figure 1. Summary of areas considered significant, sensitive, or community valued. Data was obtained from the literature, or suggested by academics or non-governmental groups (Table 1).

Table 1. References and associated information for Figure 1, summary of areas.

#	Site	Reasons/References
1	Shepody Bay and Mary's Point. NB	Migratory shore birds, mud flats, corophium, lobster spawning
2	Minas Basin- Evangeline	Parks Canada NACS
3	Scot's bay, NS	Herring spawning (Stephenson et al, 2000, and various Pers. Com)
4	Ile Haute	Pelagic/benthic coupling; high productivity; area sensitive to dragging, mining. Bird nesting island CWS, fishing, MCBI
5	Mid bay (40 fathom contour)	Deep water Mussel mounds provide habitat and food source for associated species including groundfish (Wildish, 98). High diversity of finfish during summer months (Strong and Hanke, 95)
6	Musquash AOI	Productive salt marsh and estuary, AOI CCNB, Community, FNFA, DFO-Oceans
7	Maces Bay	Ecologically significant, substantial lobster and scallop nursery function supports nearby fisheries (Lawton (1992), and various Pers Com)
8	Beaver Harbour	principal site of the focused field studies on juvenile lobster ecology, juvenile lobster densities among the highest located in the DFO-ERDA study in 1992 in the Fundy Isles region. (Lawton 1992 and ongoing)
9	Quoddy area	International Marine Mammal Association (IMMA), Parks Canada (NACS), high benthic diversity (MCBI) contains areas that are highly biodiverse, many areas are used in university studies (Various Pers Com). L'Etete Passages and some of the outer islands contain subtidal vertical rock walls which provide habitat to an abundance of sessile organisms (MacKay, 79). These communities are not generally distributed through the region, and are considered to be significant to marine conservation (Lawton 93). Significant marine mammal aggregations (Burt, 97; Gaskin; various tour operators, Pers Com)
12	Flagg cove, Whale Cove, Long Pond Beach area and Grand Manan ledges. Grand Manan NB	Parks Canada (NACS). Sand-mud flat bottom, shallow. Recorded habitat for berried female lobsters, science monitoring (Campbell 1990; Lawton 1992, and Traditional Ecological Knowledge (TEK)).
13	Gravelly, SE of Grand Manan , the Bulkhead	Right whale cow/calf aggregations. Lobster migration path, groundfish spawning (Campbell 1990; TEK; Burt 1997 (GOM report)).
14	Machias Seal island	Terns, puffins, humpbacks (SE) Bird monitoring by Canadian Wildlife Service
15	Brier Island/ the Rip	Parks Canada (NACS), whales, herring nursery, cod spawning (Coon, 99). High finfish diversity during summer (Strong and Hanke, 95),(McKenzie, 1934). High benthic diversity (Marine Conservation Biology Institute (MCBI))
16	Cape St. Mary's area	MCBI, soft bottom fauna
17	Entrance to BoF	MCBI, soft bottom faunal assemblages
18	Deep water offshore Yarmouth, Fundian channel, NE Peak of Georges Bank	Deep water corals, redfish. Canadian Ocean Habitat Protection Society, science reports
19	Canada-USA International Boundary	GOM International Oceans Wilderness

BACKGROUND REFERENCES FOR SETTING CRITERIA, RESULTS FROM VARIOUS DISCUSSIONS, AND WORLD-WIDE STANDARDS

D. Fenton

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The presentation provided a brief introduction to criteria and protected area system planning. MPA selection world-wide has often described as "*ad hoc*", "opportunistic", or "stand alone". More recently, legislation such as the *Oceans Act* and the resulting National MPA Policy, call for the development of a "system of MPAs". In Canada, each region will approach MPA development differently to reflect the unique aspects of each environment and the socio-economic and management characteristics. To date, DFO has not released national criteria or methodologies for system planning with respect to MPAs.

What is MPA system planning? From a roundtable on MPA system planning held in Halifax in 1998: *MPA system planning is a long-term planning exercise to develop clearly defined and understood conservation objectives and identifying/designating protected areas which meet those objectives.* The term "system" refers to a grouping of sites which relate or interact based on common characteristics, criteria, or objectives. System planning efforts essentially attempts to answer the questions: What are we trying to protect and where should we locate MPAs? Bradley Barr provides a further analysis of this question referring to MPA "networks".

Based on a review of international experiences the identification and selection of a system of MPAs often involves several key activities:

- defining objectives
- information collection/'inventory' (a) ecological (b) socio-economic
- planning process to identify, prioritize, and subsequently select potential sites.

This process is built upon a mapping exercise, providing the primary tool and medium for exploring MPA system design.

Several trends or issues globally in MPA planning and identification are emerging:

- representative versus distinctive features
- percentage targets (protected versus "unprotected")

- role community input (including selection).

More specifically, several MPA identification tools that are currently used include:

- delphi approaches - the role of "expert" sessions in site selection
- representative/ecosystem classification models
- inventory - overlay/ranking models.

What specific role do "criteria" or "guidelines" play in planning a system of MPAs for the Bay of Fundy. Nationally and regionally DFO has developed "purposes" and "objectives" for MPAs. However, criteria/guidelines represent a translation and reflection of objectives into practical considerations around these more general statements of intent. Internationally there is a growing wealth of literature and experience with MPA selection and evaluation. Criteria reviewed included those by the International Union for the Conservation of Nature (IUCN), the Sweden Environment Department, and the Gulf of Maine MPA Project.

Criteria are typically divided into three main types: ecological, socio-economic, and practical/management. Examples of commonly used criteria are:

Ecological Criteria

- biogeographic (rare and representative qualities; unusual features)
- ecological (important processes/life support systems; critical habitat - nursery/juvenile; genetic; rare and endangered; species "richness")
- naturalness\fragility (human induced changes)

Social/Economic Criteria

- importance/impact to commercial fisheries
- impact on all current and future activities and uses
- cultural: community values and traditions
- economic benefits, *e.g.* ecotourism potential

Technical/"Pragmatic"

- international or national significance
- level of threats
- scientific importance

- community acceptability/awareness
- compatibility of existing uses and management regimes
- duality and replication
- "precautionary approach".

How will criteria assist with MPA selection in the Bay of Fundy? From discussions to date, criteria or guidelines "unique" to the BoF context are seen as a important component to future planning and selection processes associated with MPAs in the region. According to the Sweden Department of Environment, criteria for MPA selection must have three goals:

- they must accurately reflect objectives;
- they must be relevant for the environment in which they are used; and
- they must be sufficiently easy to use to ensure they are of value to the process.

Each of these criteria described in the international arena are useful to consider within a BoF context. For DFO to establish MPAs, criteria and sites selected will need to accurately reflect the purposes outlined in the *Oceans Act*. Reviewing these purposes and how they relate to the ecological and socio-economic characteristics of the Bay of Fundy in greater detail is an important next step. These would compliment any criteria developed on a broader basis, *e.g.* national or regional.

WHAT IS THE OBJECTIVE OF A NETWORK OF MPAS? NATIONAL AND INTERNATIONAL PERSPECTIVES

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Our lives are connected by networks. Whether the internet we use to discover the world, the telephones we use to talk with one another, or the communities we live in, networks link us together. While the natural world, especially the highly fluid marine environment, is inherently connected at a multitude of scales of space and time, marine protected areas networks are designed to help us understand and define important connectivity in marine ecosystems as well as to connect the people who use, value and manage these areas.

Why are MPA networks important? They provide opportunity for effective protection and management of ecosystems without requiring protected area status for the entire area or region. Small, discrete areas are usually less troublesome to designate than entire ecosystems. They can allow all habitat types in a region to be more easily protected and make over-exploitation of any resource much more difficult. Networks can facilitate linkages to land-based protected areas. Where protection involves prohibiting human activities, networks allow socioeconomic impacts to be more equitably distributed within a region and can help resolve user conflicts. Economies of scale can also offer greater resources to address common problems and issues. The enhanced communication among network MPA managers can lead to sharing success and failures, avoiding repeating failed initiatives, and can highlight the opportunities for collaborative projects among elements of the network.

While MPA networks can offer significant opportunities, few have been successfully developed and implemented. MPA's, individually or networks, are difficult to designate because many times the public (and even on occasion the proponents) have only a vague idea of what is intended to be accomplished by an MPA designation. Considerable, vocal opposition is encountered almost everywhere an MPA is proposed. There are very few situations where the public constituency of support for marine protected areas is strong and deep enough to overcome opposition. At the core, finding the political will to do anything controversial is always difficult… and MPA's are always controversial.

There is also a lack of real "buy-in" by some MPA programs and managers. With so many significant site-specific issues to deal with, there is a perception among some MPA program managers that being a part of a network is "one more thing to deal with". In addition, there are perceived conflicts between ecosystem scale MPA networks and community-based management efforts. Most ecosystem or regional scale MPA network planning done by national governments or inter-agency working groups, where opportunities for input from the public, especially from small, local groups with interests in only one small part of the planning area, may not be obvious. While the science of MPA network design continues to be refined by the MPA research community, some general goals have been articulated. Networks should be efficient. The network should include the smallest set of areas that include the greatest biodiversity, and/or achieves other network goals, such as protecting representative areas. It should be as finite as possible. For example, if the goal of the network is to protect representative areas, the network should include all types of areas to be protected. Good network designs are flexible, providing multiple sets of areas that achieve network goals. The more acceptable alternatives you have, the greater the chances that you will be able to achieve full implementation of the network. Clear priorities should be identified to be sure that irreplaceable areas are included in all acceptable network designs. It is critical that explicit design and selection criteria are clearly and understandably articulated. If possible, replication of spatially-separated habitat types be included in the design as a hedge against unintended man-made or natural disturbances. Finally networks should be self-sustaining. The network must continue to be fully protected in then face of ineffective management of resources outside the network element boundaries. It is essential for MPA network managers not to ignore the protection and management of resources "outside the boxes", share what they learn about resource protection from their experience with other regional resource managers, work collaboratively to establish buffer zones and corridors where necessary and appropriate, and consider how users displaced by MPA designations will affect resources elsewhere in the ecosystem. Finally, the laws, rules and regulations that establish and protect the network must be enforceable.

Given the complexity of most marine ecosystems, we might never understand it completely enough to design the perfect network, but this should not prevent us from moving forward with designing, implementing, monitoring and adjusting, where necessary, MPA networks. Ideally, the initial focus should be designing networks on ecosystem scales, but process can be effectively applied to small sub-regions (like the Bay of Fundy), but ecosystem perspective should always be guidepost. The initial step in the design and implementation of MPA networks is to identify ecosystem boundaries. While this seems like the easiest step, it may be deceptively difficult, as there is no uniform and broadly accepted way to define and delineate ecosystems. Identify possible sub-regions as planning areas, as it is often considerably easier to do small chunks rather than the whole ecosystem, and this is one way to address the issue of integrating community-based management into this ecosystem-scale process. It is critical to identify and cultivate local constituencies, not only to know who to invite to meetings, but to develop a base of support for the initiative. At some point early on in the process, ecosystem-wide network goals need to be clearly articulated. For most MPA networks, principal goal will likely be preservation of biodiversity and cultural heritage, but whatever it is, shared goals are essential. If planning in sub-regions, region-specific goals can add to, but not replace these over-arching network goals. Network should be designed within context of ecosystem goals. Existing MPAs within ecosystem boundaries and/or planning area must be identified, and their contribution toward meeting the identified network goals identified. If it is found that the existing sites fall short of meeting adopted network goals (which will be the case in most coastal and ocean areas of North America), it will be essential to be able to explain to the public why new, more protective MPA's must be designated. Convening the regional scientific community to help identify areas and threats is useful for this step. It is absolutely essential that all design activities be fully transparent, conducted in public, extra efforts be directed at making the process as inclusive and accessible as possible, and all products be written in plain language. Implement full network design. This process is likely to be long, difficult, and controversial, but less so for an individual site if the development of the network design was in the full light of day, it included the full spectrum of interested and affected parties, and the network is based on clear and understandable goals. One word of warning… it is far worse to plan and deviate from that plan than to not plan at all. Make management goals at existing sites consistent. Existing sites that contribute to the ecosystem-wide goals, or ones that could contribute if changes were made in their management plans, should make their management structure and goals consistent with the Network's. Continue and enhance close coordination. This is where value-added of networks comes into clear view, as it provides new tools and resources for MPA managers to get the job done… coordinate, communicate, and collaborate. It is also important to establish good coordination with others who are responsible for management of resources outside network. Monitor, review and revise. You must be able to clearly show that the network is effectively and efficiently achieving goals.

Discussions of developing MPA networks for the Gulf of Maine/Bay of Fundy ecosystem are ongoing on many fronts and on both sides of the international boundary, but no ecosystem level process has yet been initiated. However, the Bay of Fundy sub-unit of this ecosystem could be an ideal candidate to move forward in anticipation of the more encompassing ecosystem-scale process, given the large amount of resource information available for this region, and the presence of organizations like BoFEP that could help to support such a process. There is also great interest and presence in the Bay of Fundy of governmental agencies that designate and manage MPAs. While ecosystem-scale network goals have not yet been articulated for the Gulf of Maine/Bay of Fundy, using more generally defined goals of preserving biodiversity and cultural heritage, supplemented with any local goals that may be developed, establishing an MPA network in the Bay of Fundy could help to provide leadership in this arena, and add another dimension to resource protection for this environmentally important area.

THE ROLE OF SCIENCE (BIODIVERSITY INDICES) IN SITE SELECTION AND SETTING OF BOUNDARIES, DECISION MAKING, AND DEVELOPMENT OF MANAGEMENT PLANS

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Introduction

The aim of nature conservation is the prevention of species extinction, and species and biotope orientated criteria are the most pragmatic approach to the protection of biodiversity. The selection of marine areas for nature conservation is one of several approaches necessary to provide protection to species from present and future disturbance from man's activities. Wider marine conservation measures complement conservation areas, and are essential because the openness of the sea facilitates the dispersion of pollution and wildlife. Nature conservation areas will not only protect a natural heritage but can provide direct and indirect socio-economic benefits to man. To foster the appreciation of these benefits an essential component of marine conservation is education at all levels, and continuing research to facilitate management.

This presentation was based on the experience of recommending MPA from the results of the ecological BioMar survey of 900 seabed sites around Ireland. The selection of marine areas for nature conservation was divided into two parts, the identification of important areas, and the selection of areas for legal protection. Not all areas of importance may be suitable for legal protection. The aim of this process is to establish a network of areas which will include the variety of biotopes, species and population of species. Thus biodiversity at the community, species, population and genetic levels should be protected. Large mobile species such as cetaceans, seals, birds and some fish, require larger areas and population level criteria may be more appropriate than those described here.

The main criteria proposed for identifying areas of nature conservation importance are (1) species composition, (2) the presence of species rare geographically, (3) species richness, and (4) biotope composition and richness. With adequate data, this approach is likely to indicate a suite of areas which encompass biogeographic variation and form a network of marine protected areas. With the knowledge of what areas would include a wide range of species, the selection of marine areas for legal designation (*e.g.* as nature reserves) must consider the management feasibility of each area. The latter would include consideration of existing uses, naturalness, alternative boundaries, size, and proximity to terrestrial conservation areas, in relation to management resources. The use of concepts such as representativeness, typicality, vulnerability, sensitivity, fragility, restorability, and numerical scoring of criteria were not felt necessary. This was because they were difficult or impossible to quantify, would not add to the present sites selected, or they would unnecessarily complicate transparent and clear communication of site selection criteria. Having identified and selected a suite of potential marine conservation areas, additional criteria may attract support for legal designation from other sectors. For example, designation may enhance tourism value, may protect fish breeding and nursery areas, and be an educational resource.

Marine nature conservation

Historically, nature conservation has concentrated on protecting certain species or areas of land so as to prevent species from extinction due to human activity. It has only recently begun to be applied to the marine environment as there is growing recognition of the impacts of man on the sea, particularly through pollution and over-fishing (GESAMP 1990; Kelleher and Kenchington 1992). In comparison to the terrestrial environment, the marine environment is less readily observed and less understood.

The openness of the marine environment presents a particular problem to conservation management. It is not possible for management to intervene in marine nature management in the same manner as on land (*e.g.* erection of fences, control of grazing). Almost all marine species disperse through the water (whether swimming, floating or rafting), and many have planktonic stages in their life-cycle. Pollutants are diluted and transported by wind and tide driven water currents. Indeed, all human wastes and pollutants discharged to air, freshwater and land, may ultimately enter the sea. Therefore, it must be recognised that wider measures to protect the marine environment are as an essential part of marine conservation as the management of marine nature reserves. These measures include the promotion of measures to (a) limit pollution from air, land and rivers, (b) use and harvest natural resources sustainably, (c) harvest non-renewable resources in a careful manner, and (d) prevent the artificial introduction of species to areas where they may have negative impacts on naturally occuring species. In areas identified as being of particular importance to nature conservation, human activity must be managed so as not to compromise the survival of the fauna and flora, be it directly or through alteration of their environment.

The identification of threatened species in the marine environment is particularly difficult because so little is known about the distribution of the majority of species. Indeed, many species are still undescribed and the least well known groups have the most species (Costello *et al.* 1996). However, for certain taxa there may be sufficient information to consider them to have a localised distribution (*i.e.* geographically rare), and/or to know there populations have been declining or are under threat of extinction.

Needs and benefits marine nature conservation

In addition to moral obligations to protect natural marine heritage there are sound economic reasons for doing so (Table 1). Firstly, marine fauna and flora are both directly (*e.g.* for human consumption) and indirectly (*e.g.* as food for commercial fish) of value. Secondly, they act as an indicator of the healthy functioning of marine ecosystems. Coastal ecosystems are an integral part of regional and global ecosystems, and the larger scale ecosystems are dependant on the health of their parts. In the future, the social and economic value of coastal waters is likely to increase as most people live and spend leisure time on the coast. Nature conservation will preserve natural heritage for future generations to use and enjoy.

Changes in the distribution and abundance of marine species may reflect climatic change or pollution, but whatever the cause it is important to recognize that such changes are occurring so as to react appropriately (*e.g.* reduce fishing pressure on a stock affected by climatic change or pollution). Species from whales to microbes have important roles in the nutrient flows in marine ecosystems. While some species, particularly rare species, may appear of less functional importance in such ecosystem processes, they may become important under future (perhaps different) environmental conditions. It is thus necessary to protect not only species of direct commercial value, but also species of less obvious importance to man.

Marine nature reserves have been successful in enhancing fisheries, primarily by providing a refuge for broodstock whose young disperse to surrounding areas (Alcala 1988; Russ and Alcala 1994). They can also provide a simpler, unequivocal, and more cost effective management option than other fishery measures, such as closed seasons, selective fishing gear and quotas (Bohnsack 1994). Furthermore, there is no by-catch mortality and the study of unfished populations can aid understanding of fish stock dynamics. The simplicity of the nature reserve concept, and its application to all users of the area, can also prove more acceptable and equitable to the local community. Considering the over-fishing crisis in the Atlantic and Pacific oceans, it is time to give increased consideration to nature reserves as a means of protecting marine biological resources where conventional controls have failed.

Limits of information

While general environmental and fisheries measures may protect marine life and habitats to some extent, they may be insufficient to protect rare species and habitats. The most critical stage in marine nature conservation is identifying areas that are a priority for protection. The identification of such areas is particularly difficult (in comparison to land and freshwater conservation) considering the limited knowledge and understanding of what lives in the sea and how marine ecosystems function. Additionally the information available is limited by the geographic extent of information, observer expertise, and field survey effort. While recognizing these limitations, decisions must still be made as to which areas to nominate as conservation areas. Ideally, all areas would have a comprehensive dataset comprised of information collected by standardized methods and equally trained staff. However, it is only possible to standardize expertise between observers at a general level. Skilled observers will identify more species faster than less skilled, and individual observers will vary in ability over time depending on their experience and diligence.

There are practical limitations in collecting and interpreting information on the marine environment. Even data available will be compromised by (a) natural variation in species abundance over time, (b) ability of personnel to recognize species in the field, and (c) ability of personnel to identify species when they recognize them. Some species are nocturnal and very few marine surveys are conducted at night. Other species are in cryptic resting phases at certain times of the year, and others show large variations in abundance in a locality between years due to local climatic and ecological conditions.

Any scientific study is limited in spatial, temporal and taxonomic coverage. To optimise this limited data all sources of information must be considered. Thus the marine survey of Ireland as part of the BioMar project (Costello 1995) systematically reviewed literature on Irish marine ecology (Kelly and Costello 1995, 1996; Kelly *et al.* 1996, 1997) to complement the results of field surveys. This resulted in more information for some areas than others and identified information gaps where further work was necessary. Indeed, in identifying areas of conservation interest it is important to state where further work would be necessary for designation or management (*e.g.* more detailed mapping).

In terrestrial conservation, area assessment has primarily been based on plant and bird distributions. In contrast, the BioMar project used species from a wide range of phyla, classes and orders (Table 2). As in terrestrial conservation assessment, most of these are visually conspicuous such that they are identifiable in situ. It is assumed that by including as wide a range of species as possible within conservation areas, that populations of unrecorded species will also be protected. It is desirable to test this assumption by specialised studies on the distribution of other taxa.

Criteria for marine nature conservation

Past and current approaches

Many criteria have been proposed for the prioritization of areas for nature conservation (Wright 1977; Kelleher and Kenchington 1992), and some of these have been used in the selection of conservation areas (Table 3). The terminology used in the criteria varies, probably reflecting the trends in conservation management of the time. For example, the term biodiversity has only recently become used in ecology and nature conservation. However, the use of long checklists of criteria can distract from the primary purpose of nature conservation, namely the protection of fauna and flora from human impact.

The use of conservation areas for public recreation, education, and scientific research has the potential to conflict with the goals of nature conservation (Wright 1977). As both of these uses are often compatible they are sometimes used in combination to strengthen the grounds for designation and identify the benefits which will arise from conservation (*e.g.* rich wildlife may increase amenity value).

The protection of nature may increase the value of the areas for other purposes (*e.g.* recreation, tourism, education, research), but different purposes require different criteria. As these uses are subordinate to nature conservation they cannot be used as criteria in identifying areas of conservation importance. They may usefully promote the benefits of nature conservation to the wider environment, and can thus find merit as "supporting" criteria and in developing management policy.

Numerical schemes and indices have been developed (*e.g.* Wright 1977). However, the scores and relative weightings applied to potential conservation areas are dependant on how the assessor values different criteria. Such scores may thus compound two subjective components, the criteria themselves and their individual (and unscaled) numerical values. Furthermore, the resulting scores are not comparable with studies that use different criteria or scoring systems. In addition, the provision of numerical values may conceal the underlying basis for site selection. Matrices of parameters of interest have also been used (Mondor 1992), but these are perhaps more useful for management to select conservation areas than in identifying areas of actual interest.

Traditional approaches to nature conservation involve the protection of species threatened with extinction from exploitation, and their habitats from damage and disturbance. The Council of Europe Bern Convention, and the European Union Habitats Directive (European Commission 1992), identify both species and habitats which must be protected in member states. The Convention on Biological Diversity goes a step further. This requires all signatories to protect the variety of life as both biological forms (*e.g.* genes, populations, species) and their interactions (*e.g.* communities, ecosystems). Despite the variety of criteria, the basis for all the designations was the aim to ensure the long term survival of fauna, flora, and ecosystems. It is thus proposed that the primary criteria for the identification of marine nature conservation areas would aim to conserve biodiversity, as indicated by the presence of naturally occurring fauna and flora.

Some approaches to conservation select sites on the basis of their habitats, communities and/or biotopes (Blab *et al.* 1995). Habitats are defined as the physical environment a species lives in, a community a recurring assemblage of species living in a defined habitat, and biotopes a combination of habitat and community (see review by Hiscock and Connor 1991 for fuller definitions). Such approaches may be better suited to the terrestrial than marine environment, because in the former the habitat is invariably formed by plants which in themselves are species which warrant conservation. On land, the characterising species of the biotope are also a habitat.

However, on the seabed plants are limited in distribution to shallow waters with stable substrata, are not as long-lived as trees on land, and do not modify the habitat to the degree than terrestrial plants do. The substratum and water movements usually form marine habitats, but living organisms (*e.g.* coral reefs, maerl) form some.

Until the European BioMar project, there was no international standardized system for the description of habitats, communities and biotopes. This limited the use of these units in nature conservation assessment as it was difficult to compare like units with like. The development of habitat and biotope classifications have been encouraged by the IUCN (Kelleher and Kenchington 1992), and European Commission. The latter developed the CORINE biotope classification for terrestrial habitats primarily designed on a phyto-sociological basis (European Commission 1991a, b, c, d). Within the BioMar project funded by the EC Life programme, a classification of marine biotopes was developed by the Marine Nature Conservation Review (MNCR) of the Joint Nature Conservation Committee UK (Hiscock 1995; Connor *et al.* 1997a, 1997b). The general approach and the upper levels of this classification have been agreed at workshops with representatives from CORINE and the north-east Atlantic countries. To illustrate the physical and biological inter-relationships between biotopes matrices have been extensively used (Connor 1995; Connor *et al.* 1997a, 1997b). Biotopes are another index of biodiversity, which add environmental (habitat) and inter-species (community) aspects to the species level approach. The BioMar-MNCR marine biotope classification provides a standardized way to identify, characterize and compare marine areas.

The composition of communities and biotopes will vary in space and time (*e.g.* due to biogeographic or seasonal variation in species abundance). The use of habitats, communities and biotopes may provide a useful means of synopsing, mapping, and describing the elements of an ecosystem. They complement, but cannot substitute for the identification of the actual species present. Habitats are not biological units in themselves and are thus an indirect way of protecting species. Furthermore, habitats, communities, and biotopes are recognized because of the species they contain so there is some circularity in using them as criteria. Species are the only element of biodiversity at the whole organism level that can provide a practical and universal measure of the conservation value of an area. However, only small proportions of marine species are ever identified in field surveys. The actual species recorded are thus used as an indicator of the variety of all species present. Biotopes are an indicator of both the species present and of the habitat. Considering that no species list will ever be complete, the use of biotopes complements the species level approach in evaluating the conservation importance of marine areas. Therefore, while the emphasis in conservation assessment should remain at the species level, it should be supplemented by the use of biotopes, and perhaps other indices of biodiversity, where possible.

In evaluating the nature conservation importance of an area, it is critical that the fauna and flora present are the primary criterion. It is desirable that as many species as possible occurring within a national territory are represented within nature conservation areas. It will be easier to accommodate widespread species in conservation areas than species with a more limited distribution. Therefore the limited distribution of one or more (rare) species to a locality is a useful means of identifying areas of potential nature conservation importance.

In this document, it is proposed that the process of selecting marine conservation areas be best divided into two phases. Firstly the identification of places which are of nature conservation value, and secondly the selection of such areas for designation on the basis of management considerations. Subsequently, additional characteristics may be used to support the case for selection (Table 4).

The selection of conservation areas for legal protection must consider the feasibility and costs of managing the area in terms of the resources and other areas available. Management authorities may need to prioritise marine areas identified as being of nature conservation importance against their available resources. The importance of an area for nature is independent of whether it can be managed or not. However, the management needs are dependent on what species occur there. Whatever approach is taken it is important that the reasons why areas are being proposed for conservation are clear, justifiable, and transparent. Criteria that are few and simple will be easier to interpret, explain, and for the public to understand. It is also necessary to differentiate between criteria that are based on observations from those based on opinion. In this paper, the identification of areas of nature conservation importance and selection of areas for legal designation are thus dealt with separately.

Identifying areas of conservation importance

Species composition

The inclusion of populations of as many species as possible within the (proposed) network of conservation areas is necessary, as an aim of nature conservation is to protect as many species as possible. The contribution of any defined area to the network can be measured as the percentage the species present contribute to the total species list for the region. While it must be recognised that all areas will not have been surveyed in an identical manner, this calculation can be conducted from selected datasets depending on the comparisons required. For example, the BioMar survey used the same staff and methods to survey hundreds sites in Ireland (Costello 1995). Its results for an area can be compared to the total list of species recorded in the survey. As information accumulates, eventually it may be felt valid to compare the total species list for the area with the list of all species known from Ireland, British Isles, Northern Europe, or some wider region. The greater the proportion of the national fauna and flora protected within a single conservation area the higher national priority it would receive.

Geographically rare species

Rarity is defined here in terms of geographic distribution rather than population size in an area. This approach was also adopted by Sanderson (1996b) in developing nature conservation assessment criteria in Britain. From field surveys and scientific literature, it will be possible to identify the occurrence of rarely recorded species in certain areas. While a species may be rarely recorded for many reasons, it would be dangerous to assume it is common elsewhere without compelling evidence. Hence, it is prudent to consider a rarely recorded species as rare until found otherwise.

Species of local distribution are more vulnerable than widespread species to extinction as in the event of local extinction, re-colonization from elsewhere is unlikely. They therefore merit special recognition in conservation. It is worth noting that species rare in distribution do not necessarily occur in areas of high species richness (Kareiva 1993; Prendergast *et al.* 1993). Although one cannot substitute richness for rarity or vice-versa, areas with more species will tend to have more rare species.

Species richness

Within a defined area a wide variety of habitats and/or species may occur, *i.e.* the area is notably rich in habitats or species. Richness thus differs from species composition in that it ignores the identity of species and is a reflection of the size of an area. This criterion is particularly important in defining the marine boundaries of the conservation area so as to maximize the range of species and habitats covered.

Because an area is rich in species for certain taxa does not imply that it will be rich for other taxa. The maximum overlap in (10 km^2) species rich "hotspots" for birds, butterflies, dragonflies, aquatic plants and liverworts in Britain was only 34 % (Prendergast *et al.* 1993). Presumably this pattern reflects the different habitats and spatial scales at which taxa live. However, Prendergast *et al.* (1993) did find that if all the hotspots were combined for a taxon then 48 - 100 % of species in the other taxa were also included.

Biotope composition and richness

Biotopes are identified from their dominant species and habitat characteristics. Areas with more biotopes will thus have more habitats, and consequently a wider variety of species, than areas with less. The number of biotopes in an area (biotope richness) is an additional and complementary indicator of biodiversity to the use of species.

Other "scientific" criteria

Other conservation designations in use mention the use of criteria such as endangered, typicality, representativity, vulnerability, sensitivity, fragility, and restorability (Table 3). These and other criteria are not felt necessary in identifying marine areas of international conservation importance for the reasons outlined below, including the fact that the already mentioned criteria will have included the same species and habitats.

Endangered

This is a very important criterion for prioritizing conservation action in both the protection of nature and commercial biological resources. Such species may be covered by the already proposed criteria because they will be geographically rare. If they are not rare, over-harvesting may still endanger them, in which case fishery and other regulations may be applied for protection. In the case of commercially exploited species, there will probably be some population abundance information on which the threat to the species (and IUCN criteria) can be assessed.

Typical and representative

In selecting areas that include (a) populations and records of as many species occurring within the national territory as possible, (b) rare species, and (c) many biotopes, it is anticipated that typical and representative habitats and biotopes will be included. However, the results of such assessments should be cross-checked against the list of habitats and biotopes identified in an appropriate biotope classification to identify possible omissions. The concept of using typical or representative biotopes may have been intended to protect 'good' examples of biotopes; good being defined in terms of species richness, naturalness and having healthy populations of the dominant species (*e.g.* a natural regenerating oak woodland). However, these aspects can be individually assessed.

The MNCR define typical biotopes as the average, the average being based on the existing recorded biotopes. It is thus dependent on bias's in available data, and can only be calculated for common biotopes. Considering the limited resources available for nature conservation, it would seem easier to defend protecting areas with the 'best' (species and biotope rich, rare species present) rather than the 'average'. For this reason, and the likelihood that typical areas will be encompassed within areas proposed on other criteria, typicality and representativity were not used as criteria in by the BioMar project in selecting marine nature conservation areas in Ireland.

Vulnerability, sensitivity, fragility, and restorability

The terms vulnerable, sensitive and fragile are entirely dependent on the type of threat and its likelihood of occurrence. It is difficult to predict the future threats to marine areas and life due to the limited understanding of marine and global ecosystems, and the rapid developments in marine technology. For example, salmon farming was not anticipated 40 years ago. With the limited knowledge of the biology and ecology of marine species it is very difficult to assess a species potential for recovery, and even more difficult to predict the restoration of a community. Regardless of real and hypothetical threats, populations of rare species are more likely to be endangered than species of more widespread distribution because local extinction will have a greater impact on species of more limited distribution.

Type localities

The area from where a species is first discovered, its "type" locality, may produce other species new to science, particularly if the source of the species was a rare habitat. The population of a species in its type locality forms the reference from which the description of the species is based. Protection of this population is thus of value in scientific research. Recently (in past few decades) described species are likely to be known from only a few localities (*i.e.* they are rare). Type localities tend to be either areas that have received more scientific attention than others such that their fauna is better known, or which include habitats which have been rarely studied. These areas may have attracted attention because of the richness of their biota. Areas that are type localities may already be of conservation interest on grounds of species composition, richness and rarity. Being a type locality may be a criterion for scientific interest, but is not proposed as one for nature conservation.

Species at their geographic limit

At the limit of their geographic range, species may be rare and not living under optimal conditions (*e.g.* temperature may inhibit regular spawning). These factors may be selective such that the populations become genetically distinct from individuals at the centre of their geographic range. Biodiversity includes both biological variety at the species and genetic level. Hence, even if species occur rarely in Ireland because they are at the limit of their range, the fact that they may occur in greater abundance elsewhere should not necessarily downgrade their importance in conservation. Indeed, these species provide an indicator of the limits of biogeographic regions and thus help identify areas of importance as part of a network of conservation areas. The occurrence of isolated populations beyond the usual limits of their range is well know in terrestrial and freshwater systems, and a popular criterion for selecting areas for conservation. Species with a Lusitanian distribution and glacial relics (*i.e.* survived since last ice age) are of special interest in the natural history of Ireland for example. Relic populations are also possible in the sea. For example, the warm (relative to open coast) summer temperatures in the Lough Hyne marine nature reserve appear to permit the existence of Mediterranean species otherwise absent from the region (Costello and Myers 1991). Changes in the distribution and abundance of species at the limits of their geographic distribution may also provide first indicators of climatic change in marine ecosystems. The occurrence of species at the limit of their distribution is thus worth noting in selecting areas of national conservation importance, but is less valuable at an international level. Such species will also contribute to species and biotope composition and richness and thus be included in these criteria. It is thus considered that species at their geographic limit are adequately included within the proposed criteria for assessment of areas, and may be of more value in assessing the national importance of areas and developing environmental monitoring programmes.

Rarity in abundance

Another form of rarity is the abundance of individuals in a defined area. In many natural communities, most (*e.g.* 75 %) species occur at less than 1 % of the abundance of the common species. Indeed, one or two species may contribute more than half of the community in terms of numbers of individuals or biomass. Thus in a richer biota more species will be rare in abundance.

Some taxa (*e.g.* predators, parasites) occur at low densities naturally. Species recorded in very low numbers may or may not maintain populations in the area, and may reflect dispersal from adjacent areas (Costello and Myers 1996). Species may also show great fluctuations (by factor of 10 or more) in abundance not only spatially but also during a season and between years. Thus observations on a few sampling occasions can only be considered to provide a crude approximation of actual abundance. For these reasons rarity in terms of abundance or biomass is not proposed as a criterion in conservation assessment.

Management criteria

Naturalness and existing uses

No area of the coast or sea has not been affected by human activities to some extent. Areas which are polluted, have introduced species, or artificial habitats, may or may not be of conservation interest. The criterion of naturalness has a circularity of approach in that the degree of alteration is determined by the change in the composition of the natural fauna and flora. If human impacts are already considered to have compromised the viability of species of conservation interest, then alternative areas (if available) should be selected for designation and management. It would be more effective and less costly to protect nature in areas less disturbed (polluted) by human activity. Naturalness is thus considered a criterion for conservation management rather than for assessing the importance of an area for nature.

Some estuaries (*e.g.* Baldoyle estuary, County Dublin, Ireland) subject to organic enrichment from sewage and other sources are important sites for bird conservation. The occurrence of species of conservation interest in a polluted area may be because they benefit from, tolerate, or are unaffected by pollution. Parts of Cork Harbour are very polluted but have species that do not occur elsewhere in Ireland. At least some of these species have been accidentally introduced to the harbour. Introduced species do not tend to need protection from conservation, and some are considered pests (*e.g. Sargassum muticum,* Boaden 1995). Their presence is thus not considered necessary in conservation assessment here, although it may be recognised that they may have altered the natural species composition.

Species of conservation interest may occur on artificial structures in the sea, such as ship-wrecks or piers. These species may or may not occur on adjacent areas of seabed. For example, a ship-wreck on a sedimentary seabed may provide the only examples of species which occur on hard substrata for the area. However, on a wider spatial scale, these species must occur on natural substrata and the biota of artificial structures are unlikely to contribute to biodiversity at more than a very local (few km^2) level.

Boundaries

In order to designate marine conservation areas, the owners and users need to be consulted, and the boundaries defined (Kelleher and Kenchington 1992). Because of the openness of marine systems, buffer zones and the management of areas beyond the conservation area, are particularly important. For these reasons, the IUCN guidelines expect that marine protected areas will tend to be larger and less fragmented than terrestrial areas (Kelleher and Kenchington 1992).

The boundary should encompass (rather than border) the habitats of conservation interest, and include a buffer zone where possible. Choosing the narrow entrance to a sea inlet as a boundary may not be suitable if the entrance itself is of conservation interest, so an area of adjacent coast should be included. It is proposed that boundaries follow natural features of the coastline visible from the sea and land, such as headlands. It is important that when a person is within the conservation area that it can be recognised in the field. Additionally, the latitude, longitude and depth of all boundaries should be stipulated as most commercial fishing boats and larger yachts have navigational and depth detection equipment. It may be possible to have these boundaries indicated on marine charts, and special marker buoys may be used if necessary. In applying boundaries to a marine site, the proximity of land-based sites of conservation (be it geological, ecological or archaeological) may be considered as it may be easier to delimit and manage an integrated coastal site.

Size of area

There are several benefits in having a larger sized conservation area. Firstly, the full habitat of species with large territories or individual range is likely to be covered. That the range for many marine species is unknown does not mean this principle is weakened. Secondly, the population sizes of particular species will be larger in a greater area of their habitat. The larger a population size the less likely it is that a population will become extinct due to a natural or man-induced catastrophe. There are also management benefits in that the management cost per unit area decreases with increasing area. It is not only widely accepted that bigger reserves are better for conservation, but that several protected areas are desirable for many species to account for local extinction's (Soule and Simberloff 1986). The protection of different populations promotes genetic diversity, and acts as insurance in case of local extinction's.

Management resources

Last but not least, for a proposed conservation area the management authorities must balance the likelihood of success of conservation against the urgency in relation to threats, the resources required to designate and manage the area, and the presence of alternative areas. In all these factors the understanding and support for conservation will be aided by investment in public education and the availability of information.

Education and research

Marine education must be promoted at primary, secondary and tertiary levels as this will stimulate a public understanding of marine ecosystems and the importance of conservation. To some extent this has been taking place through general popular media. However, information of local relevance must also be provided at a local level. To facilitate this, it would be valuable to identify areas of importance for marine education due to the variety of habitats and species representative of those occurring around the coast. Published guides to assist school teachers, and promotion by local wildlife rangers would all have a role in local education. This would also relieve pressure on conservation areas for disturbance due to trampling and collecting.

It would also be advisable to promote marine nature conservation in general, and provide local marine educational information, distinctly from the designation of marine conservation areas. Otherwise it may appear that the information is being used to sell the designation of a particular site. The latter should also be conducted within the context of wider coastal zone management.
Important criteria for assessing the educational value of marine areas include accessibility, public safety, the clarity and simplicity of biological phenomena (*e.g.* intertidal zonation), and resilience of the area to people pressure (*e.g.* trampling, collecting, turning over of stones). None of these criteria are important for nature conservation assessment. Scientific research may also prefer areas with ease of access and safe working conditions. However, scientists may give particular importance to the scientific history of the area and its wealth of background data.

From field observations and literature, it may be possible to identify other resources in the proposed conservation area that may immediately or in the future benefit from nature conservation.

It may be of value for both management and political reasons to identify these potential benefits at an early stage, and to note whether existing activities (*e.g.* fish farming, fisheries, angling) may pose a significant threat to the fauna and flora.

Communication with the public and local resource users should begin before the designation of marine conservation areas. This should aim to build partnerships and develop a management plan for the area in advance of formal designation. In the absence of this process it is likely that local communities will feel disenfranchised by the process and that they will object and not co-operate with it.

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Table 1. Some of the benefits of marine nature conservation areas (*e.g.* reserves). The degree of benefit will depend on the approach and success of conservation management.

Fisheries

- Refuge for commercial species broodstock and spawning. The young will disperse outside of the reserve
- Nursery for juvenile fish of commercial species from damage as bycatch in fisheries

Aquaculture

- Source of animals for commercial ongrowing
- Less pollution improves water quality

Public amenity, tourism

- Natural scenery (due to development controls) increases value of area for walking, boating, yachting, etc..
- More large fish for angling
- Better water quality due to less pollution
- Nature watching (especially birds, dolphins and whales)

Education

- School and public groups can witness nature relatively undisturbed by human activity
- Researchers can study how life operates under natural conditions
- Fosters appreciation of natural heritage and social value of nature

Ecosystem function

- Maintenance of fauna and flora populations which can disperse to areas more disturbed by human activity
- Absorption and recycling of nutrients from sewage and agricultural waste discharges

Future generations

- Sustained development of natural resources

Table 2. The phyla and classes (in capitals) and orders of taxa identified to species level on field surveys by the BioMar project in Ireland.

ANIMALS		PLANTS	
BRYOZOA		ANGIOSPERMAE	
CHELICERATA	Pycnogonida		
CNIDARIA	Anthozoa	PHAEOPHYCEAE	
	Hydrozoa		
	Scyphozoa	CHLOROPHYCEAE	
CRUSTACEA	Decapoda	RHODOPHYCEAE	
	Amphipoda		Bangiales
	Cirripedia		Ceramiales
	Isopoda		Corallinales
ECHIURA			Cryptonemiales
ECHINODERMATA			Gigartinales
	Asteroidea		Hildenbrandiales
	Crinoidea		Nemaliales
	Echinoidea		Palmariales
	Holothuroidea		Rhodymeniales
	Ophiuroidea		
INSECTA			
MOLLUSCA	Cephalopoda	LICHENS	
	Bivalvia (Pelecypoda)		
	Gastropoda (Prosobranchia)		
	Opisthobranchia		
	Polyplacophora		
NEMERTEA			
PHORONIDA			
PISCES			
PLATYHELMINTHES			
POLYCHAETA			
PORIFERA	Calcarea		
	Demospongiae		
SIPUNCULA			
TUNICATA	Ascidacea		

Table 3. Examples of criteria used for the selection of nature conservation areas.

Organization	IUCN		Council of Europe		European Community (Union)	
Designation	World Heritage Site	Biosphere reserve	Biogenetic reserve	European Diploma site	Special Protection Area(birds)	Special Area for Conserv-ation
Unique -						
phenomenon	+					
landscape		+				
habitat			+		+	
Beauty	+			+		
Culture	+			+		
Evolution	+					
Research/science		+		+	+	
Education		+		+	+	
Genetic		+				
Endangered species	+		+		+	+
Restorability						
- habitat		+				+
- species						+
Typical						
- habitats			+		+	+
- species			+		+	
Rare						
- habitats			+		+	+
- species			+		+	
Area					+	+
Population						+
Location						+

Table 4. Criteria used for the identification, selection and promotion of marine conservation areas in Ireland by the BioMar project.

Scientific criteria for the identification of areas of nature conservation importance

- Species composition
- Geographically rare species
- Species richness
- Biotope richness

Management criteria

- Naturalness and existing uses
- Boundaries and proximity to terrestrial conservation areas
- Size of area
- Management resources

Supporting factors

- Fisheries
- Aquaculture
- Recreation (amenity)
- Cultural heritage
- Tourism
- Education
- Research

COMMUNITY INVOLVEMENT AND ROLE IN IDENTIFYING SITES

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The Conservation Council of New Brunswick is a non-profit registered charity, formed in 1969. We have a board consisting of 24 volunteer directors from across the province, a permanent full-time staff of four, one full-time contract staff person (dedicated to the Musquash Estuary MPA Campaign), and several temporary or part-time contract staff. We are not a community group, as the term is commonly understood. That is, we are not geographically limited in our program scope, and while policy and direction are set by volunteers, the day to day work of the Council is not carried out by them.

We work closely with many community-based groups throughout the province on many projects. In reference to the issue of identifying sites as potential MPAs, CCNB certainly 'qualifies' as an outside, third party or unsolicited nominator of an MPA. In fact, we officially nominated the Bay of Fundy's only Area of Interest -- the Musquash Estuary just west of here -- in October 1998, and we have been actively involved in moving the process through to final designation ever since. Putting myself in the shoes of civil servants charged with developing an MPA system plan, such third party nominations could well be an unwelcomed, possibly unhelpful, diversion from a more systematic, integrated approach to site identification. On the other hand, if the case for a site is well developed and documented, and comes with the intent to be involved throughout the process and beyond, the third party could become a valuable asset in advancing the MPA agenda.

The CCNB has been concerned about Musquash since the 1970s when a Liquified Natural Gas terminal was proposed for the area. Together with local people and groups we put a halt to that development. In the 1980s, we joined with the local fishermen to fend off a proposal for a coal port. Finally, in 1997, the Oceans Act presented us with a tool by which we could work proactively to protect this special area from any heavy development that could degrade it. Without the ability to nominate the site ourselves, it would have been much less helpful. It would have been left to us to lobby both politicians and bureaucrats for its candidacy, a task that would have far outstripped our organizational capacity to sustain. Whether or not Musquash made it to the nomination stage, let alone beyond this, would have been far more arbitrary and far less timely. Our ability to nominate automatically injected our site into the process, and required consideration and a response from DFO.

Another advantage of this third party nomination must not be understated. In nominating Musquash, we were able to officially "launch" a Musquash MPA Campaign. This was a trigger to garner public and financial support for seeing it through to conclusion. Had the nomination not been in the hopper, it would have been very difficult to generate public interest and support, especially over the time frame that the process imposes. Just as important, it would have been virtually impossible to raise any more than preliminary and modest funds to support the process.

I want to stress the importance of fundraising. Since we started on this road, a year before we officially nominated the site (even before the Act was proclaimed), CCNB has raised approximately $140,000 to support the process towards final MPA designation. This has hired a full-time campaign co-ordinator for 3 years (David Thompson has just begun his 3rd year). It has signed up support from key organizations and stakeholders in the area. It has hired avifauna and flora surveys. It has produced a cultural, economic and landscape profile. It has commissioned a proposal for long term biological monitoring in the estuary. It has produced public education tools – poster, display components, and extensive photo and video documentation of the area. It has collected GIS data. It has compiled landowner information and supported the Musquash MPA Planning Group.

It has staged events like the Musquash Paddle, community open houses (more are planned), press conferences, press and other boat tours. It has provided many meetings with politicians and senior civil servants to garner support. It has monitored activities going on in and around the estuary, bringing bad practices to the attention of provincial and federal authorities. It has been a liaison for DFO into the community and the estuary, and has "encouraged" the process to move along. And on and on.

The point is, CCNB has doggedly paved the way for this nomination to be successful. In doing so, we have added incredible value to this process. Even so, the process has been painfully slow. It took nearly 16 months to move from nomination to AOI. This was not because of a lack of information or merit, but had everything to do with the slow grinding of gears inside the bureaucracy. Had CCNB not been there to move things along, it is questionable whether the Musquash nomination would be as far along as it is.

The outstanding question, then, is how to productively engage third party nominators in the process of establishing a system of MPAs. Indeed, the involvement of third parties or NGO or community groups or interest groups will be critical to the success of the system. They shouldn't be expected to raise gobs of money for the project, but if they simply bring the community along with the process, they will be making a vast contribution.

The key to respectful involvement of such groups, however, is to provide the opportunity for them to be proactive in nominating and then garnering support for the nomination. The criteria for a nomination and the documentation required to support it, could be quite stringent – if a group is committed to a site, they will compile the information they need to justify its nomination. This can only benefit the marine environment.

SUMMARY OF BREAK-OUT GROUP DISCUSSIONS

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Following the speaker presentations, participants to this workshop divided into three MPA teams to discuss various issues. The overall goal was to address questions on criteria, community involvement and process.

Team 1. Refining ECOLOGICAL objectives and selection criteria

Team Leader: Maria-Ines Buzeta

"Conservationists are far from able to assist all species under threat, if only for lack of funding. This places a premium on priorities: how can we support the most species at the least cost?". Myers, N., R.A. Mittermeier, C.G. Mittermeier, G.A.B. da Fonseca and J. Kent. 2000. Nature 403: 853-858.

The goals of this group are to refine ecological purposes and reasons for MPAs in the Bay of Fundy. The group will identify key ecological criteria for use within the BoF. If possible, discussion should relate to specific areas, proposed or new or from "summary" map. The group has the option to review sites using the Oceans Act (OA) criteria, or to develop further guidelines for review within a BoF context. As well, they can suggest tools, indicators, information needs, and "minimum acceptable" information requirements for identifying and selecting specific sites. The definition of the Precautionary Approach, and if and how to apply it in site selection, should be discussed.

Team Composition

Team 1 was small; five individuals plus the team leader; however, it was a diverse and therefore well rounded team. It was comprised of :

- an industry representative with a science education
- an environmental sciences student

- a community member with science background and an in-depth knowledge of the geographic area
- a scientist working in the BoF, and
- a coordinator for Bay of Fundy Marine Protected Areas.

Question - What ecological criteria should be used in BoF? Give examples.

There are already sufficient criteria available for use.
Each individual will have a different set of criteria:

- Too many criteria, move too slow/ don't make progress if criteria are too stringent.
- Oceans Act itself covers most reasons, with the possible exception of "representativeness".
- Not all OA criteria are ecologically relevant (such as for education and research).
- By specifying "biodiversity" as important, we may be overlooking other important areas, with low diversity (*i.e.* source areas).
- Even if a site fits all criteria but is in the middle of an aquaculture site, politics will come into play. Example given was Sandy Island.
- How does the WWF framework apply, will/can it be used (seascapes/natural regions)? Especially if the biological information is not available? Discussion on scale as a problem in the BoF, *i.e.* natural regions are very large geographic regions, and little acceptance of a large protected area (in view of the Marine Park efforts earlier).
- Should you protect a resource used by diving industry and visitors? For example, Black Rock (area of high biodiversity of benthic macro invertebrates). Should it be one of many "nodes", useful also to re-seed other areas?
- Every area contributes something to the understanding of the Bay- there has to be a limit on number of sites.

Recommendations

Participants felt that there are sufficient criteria already developed and used worldwide, and these are encaptioned within the reasons stated in the OA, with the notable exception of "representativeness" that should be added in. There is a reluctance to suggest that any specific criterium should apply, as not only will different stakeholders have different views, but more importantly it suggests that, for example, areas of low diversity are not as important in the ecosystem. Flexibility should be used when reviewing sites, as too many stringent criteria will bog down this process.

The group opted to defer the question of ecological criteria for identification and selection of MPAs. Instead the discussion was focused on approaches (or philosophies) for identifying, selecting and establishing MPAs.

Question - What tools should be used to identify and evaluate sites?

- There is an incompleteness to any cataloguing of available information for a site. That is, (so-called) objective ecological criteria cannot be applied to a site without the required scientific information.
- List all potential sites, then identify all "obtainable" sites, then prioritize.
- Go for areas with least resistance.
- Bring all sites in for evaluation at the same time; they can not be reviewed in isolation.
- Identification won't always be scientific, rather scientific information will be used to back up, modify, or retract decisions.
- People may feel that a site is worthy of protection but not have the science or the resources to gather the information, summarized as the "fall in love first, justify later" philosophy.
- "Golden opportunity - do it".

Recommendations

Comprise a list of sites obtained via any scientific literature available, or sites that others suggest, and bring all potential sites to the "table" at once for discussion and evaluation as a package. A site being "obtainable" was seen as key in site evaluation, and while scientific justification should be looked for each site, it won't always be available, or be at the basis of people's support.

The point the participants made was that in selecting a site, one should not feel constrained by what is perceived as obtainable. Rather they should aim to choose the best sites and not worry about what is 'politically palatable' (this was the precursor to the "fall in love first, and justify later" comments above). Initially one should try and pick sites that are optimal (from an ecological standpoint), and not worry about opposition/compromise right away, since politics and special interest groups will enter the process at some stage in any case. MPA implementation will be the negotiation process, but the opening position should not be an ecological compromise. Compromise will happen as negotiations proceed anyway, so the initial position should not be watered down.

Question - Science and the general public recommend a comprehensive scientific overview and a systematic review of the requirements for appropriate ecosystem management in the BoF. At the same time, there is a need to quickly identify valued areas from available, scientific, social and traditional information, and to begin discussion on the protection needs of these areas before they are further degradated. What do you think would be the "minimum acceptable" information required for identification, selection and decision making? Give examples.

- There will never be sufficient information to suit everyone, someone will always want more and this costs time and money. If there are too many sites, too many resources will be needed.

- There is sufficient info out there for "some" cases, such as Head Harbour for whales and porpoise (Gaskin and the Pittsburg refinery hearings) and other marine mammal aggregations and migration.
- Some spots are known to be "highly biodiverse" by locals, especially divers, this would identify them, even if studies are needed later to quantify.
- Find out what is already known about all the potential sites. These should be summarized and presented back for discussion.
- Systematic approach would work in the Arctic or a remote area with few users, but industries aren't waiting here, there are too many users.
- They (industry) need to know how many sites, and how much is going to be protected, so that they know what to expect, and where they could operate.
- Managers always want more studies, process gets bogged down.
- Systematic studies should be done in parallel to identification.

Recommendations

Some felt there was sufficient information available for many sites, and that we must start with local information (TEK) for others. Although industry will benefit overall in the long-term, they need information on where then can continue to operate, something that identification of all sites at once can do for them.

Question - The PA is defined as "err in the side of caution". How could this be used, or should it be used, in site identification, selection and decision making?

- Criteria will help identify and review sites, but these sites also have to be supported by the communities and users, so not all will become MPAs. Some will not be acceptable to users anyway.
- "Don't compromise" the objective/position, identify them all and use all of them for discussion. At the same time start studies that will give the information required to see if decision was correct. If you find out that it wasn't needed or right, then a site can always be withdrawn from the plan.
- If plan doesn't capture all requirements for protection, then can always "release" some sites.
- The Bay is going downhill; phalaropes already diminished… too much compromising, no decisions are made, but if the Bay is degraded, it will affect all industries.
- PA is implicit in the Oceans Act and in identifying sites in view of little information.
- This program was viewed as a golden opportunity and that we should "do it".

Recommendations

The objective (of a system of MPAs in the BoF) should not be compromised, and we should be precautionary by identifying sites to the best of present knowledge. At the same time proceed with studies to verify decisions, and modify plan (let go of some sites if not needed) accordingly when the information becomes available.

The group recommended to first put together the best possible network of MPAs from an ecological standpoint, and bring these out for discussion, without watering down for political reasons. Consultations and negotiations later on will modify the plan.

Additional theme discussed - a system of MPAs

- The "borg" concept of assimilation, where we can think nodally, each small area being a node.
- Large marine park was a disastrous concept.
- Distribute small sites, less troublesome.
- Distribute socio-economic impacts.

Recommendations

Stay away from identifying large areas in the BoF; think in small nodes, joined together to form a system.

Team 2. Defining community values and "criteria"

Team Leader: Paul Boyd, Department of Fisheries and Oceans, Oceans Branch, Antigonish, NS

The goal of this working group was to identify key community issues/values for both site identification and selection. Communities have begun to put forward sites in the Bay of Fundy and are expected to contribute to the development of a system plan. Therefore it is important to capture their views on what features/areas are important to them.

Team Composition

- a representative of a local NGO
- a resource management consultant
- a rural planner (Province of New Brunswick), and
- two representatives of the Department of Fisheries and Oceans.

Question - Characterize the current level of understanding/support for protected areas in the BoF?

Participants felt that although local communities are aware of the MPA program, understanding is generally low overall. It was noted some smaller groups with direct interest in mpas fully understand and are highly supportive.

The commercial fishing community is generally opposed to protected areas; this was summarized as high awareness, low acceptance. Participants felt commercial fishers do not fully understand the benefits of mpas, they view them as more restrictions.

The tourism industry is supportive of mpa initiatives - "build it and they will come"
It was suggested that the way to raise understanding and support for protected areas is through dialogue- public consultation, community participation, and an open-transparent process.

Question - How will we identify sites of community interest?

It was felt that if DFO continues to educate and raise awareness, the sites would come forward. Local knowledge is a good starting point. DFO must provide the science. Community based groups must be encouraged to participate in management.

Questions - What are the MPA objectives of the BoF community? What types of sites are of interest to the community? What type of "ecological features" should be captured from the community perspective, e.g. those that protect the fishery resources, those that provide research opportunities, or those considered "unique" from community perspective (Musquash)?

Participants from around the bay feel there is no defined BoF community, it is an ecosystem with surrounding communities. Sites of interest to the communities are unique areas and critical habitats; the group felt areas important to shore birds are obvious important areas.

The type of ecological feature depends on the interest group, such as ecotourism possibilities or natural historic areas.

The Musquash perspective is one of ecological function. Musquash is viewed as a working ecosystem.

Question - What key criteria would the community design as part of the MPA selection process?

This group felt that criteria are not clearly or fully defined in the Oceans Act. They felt that key habitat or irreplaceability is important features. By selecting an area of importance to the local community, unknowns will be uncovered - we must start somewhere.

Question - What are the key economic/social/cultural issues to address in identifying/selecting a particular site?

The traditional fisheries of a site are important; we should know the history of an area and respect it. Tourism also has to be recognized and considered in the selection of a site.

It is important to recognize the economical impact of a protected area, loses /gains and potential trade off.

Local or community based knowledge is critical in these issues.

Questions - What level of support from the community is required to proceed with a particular site? Should this be a requirement for protection? How to deal with sensitive areas that are not supported or of community interest?

This section took the most discussion time, we talked about areas that could be of importance on provincial, national and international scope but did not have the support of the local community. It was mentioned that Parks Canada had been in this situation and the scars have not healed even into the next generation.

Education is the key factor in this situation; DFO must educate and raise the awareness of the benefits.

Each site is unique; the message must be site specific, put the over all objectives on the table.

If the local community can not buy into the proposal, it would be best to provide optional tools to work towards any common goals.

Support from the local community especially the fishing industry is key. The group viewed some form of community based management as critical.

Recommendations

Local interest within the community group and interests is key. Locals will recognize the importance of the area first. DFO must provide the public education and the science. For the sake of protecting a critical area it is important to select the proper management tool, to ensure long-term objectives are met.

Team 3. MPA system planning for the BoF (defining the steps ahead)

Team Leader: Derek Fenton

What would a "process" for MPA development in the BoF over the next 2-5 years look like? The goal of this team was to identify key elements of a MPA system planning effort (identification and selection process) for the Bay of Fundy area. The team was primarily composed of participants from outside the Bay of Fundy area, including from the United States, British Columbia, Russia, as well as local interests. This provided the opportunity to look at other jurisdictions and the experiences in devising a process. As well, terrestrial examples of protected area plans were discussed. A "planning area" encompassing the entire Bay of Fundy was chosen in order to explore the possibility of a broad regional planning process, that would compliment any local planning efforts.

Team Composition

- a US senior policy analyst, NOAA
- a DFO oceans manager
- an NGO representative
- a European scientist working on environmental remediation, and
- a marine ecologist.

Questions - Who would be involved in designing the system? How do we organize ourselves in the BoF, e.g. committee? What are the responsibilities of any group formed?

Ultimately everyone who has an interest and stake in the Bay of Fundy would be involved at some level in both identifying and establishing a system of MPAs. Each major government department, the fishing industry, environmental groups, and academic interests, to name a few, have a part to play. Nevertheless, distinctions were made between participation on an individual site by site basis and that of the broader scale issues and planning that effect the entire Bay. Different players are expected in each process.

With so many players in the Bay of Fundy what is the best means of organizing the process to identify and come to consensus on sites? Different players bring different information or benefits to the process. Scientific information is often concentrated in certain organizations or individuals. The broader community brings a wealth of ecological and community use information to the table.

The wide variety of government departments exists and each needs to convey its jurisdictional interests. This poses a challenge in terms of limiting the numbers of people involved and developing an effective working relationship among different interests. BoFEP established a MPA committee two years ago, however this group is not active at this time.

One model which was discussed by the group in detail was the Pacific MPA Strategy in British Columbia. This Strategy has been established over the last two years to encourage joint planning and decision making on protected areas on the Pacific coast.

The team did not have sufficient time to design a process for the BoF. This is a topic for broader discussion, involving those with a greater stake in the end result. However, the team discussed what would represent some of the main elements of the process include:

- Intergovernmental committee - composed of provincial, federal and municipal interests. The committee would address intergovernmental coordination issues, focusing on agreements on specific sites and an endorsement of the MPA system concept.
- Stakeholder committee – include representatives from all major interests around the Bay, including fishing, tourism, ENGOs, shipping etc. The group would need to be a balance between maintaining a manageable working group and accommodating different views. May provide the best forum in which to explore community identified and sponsored sites of interest.
- Science committee – composed of key researchers with an interest in MPAs around the Bay. Primary focus of this group will be to coordinate information collection, and would direct the research required for MPA identification and design

Each committee would report to one another on a regular basis providing mutual direction among each. A key question for the group concerned the decision-making aspects of the planning process. Who will make the final decision on which sites move forward? Individual departments with protected areas legislation (Oceans Act, Wildlife Act) ultimately make the decision to proceed with a site designation. Nevertheless, recommendations from a broader group would greatly assist these departments in both identifying and prioritizing sites of mutual interest.

Question - What are the key planning considerations or expected issues to emerge during this planning effort?

- Relationship of MPAs to existing and emerging integrated management/planning processes in the Bay.
- Relationship with existing resource decision-making activities.
- Involvement of all agencies with protected area responsibilities in the marine environment.
- Address the lack of information (ecological).

- Level of information required (or level of uncertainty) for planning.
- Develop a "guide" or criteria to assist with decision-making.
- Timeframe (if too slow, does it affect outcome?).
- Amount of flexibility (*e.g.* use of precautionary approach).
- General understanding of the concept by many key participants.
- One site underway – Musquash demonstrate the site level processes at work.
- MPA planning efforts across the Gulf of Maine (Canada and U.S. programs, and planning interests). Network broader than BoF.

Questions - How will the process deal with sites that have already been brought forward, or with new ones identified? How to obtain input in a timely fashion (e.g. all at once rather than as a continuous flow) and how to priorize these?

These will be the primary issues that the planning process will need to address both early on and throughout the development of a system of MPAs. One limitation of only proceeding with known sites is the lack of resources and effort into designing and researching the full system. A balance between the two planning needs will need to be met.

CONCLUSIONS AND RECOMMENDATIONS

M.-I. Buzeta[1] and D. Fenton[2]

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1. There are sufficient ecological criteria already developed and accepted worldwide, but "representativeness" should be added in, and flexibility should be used when reviewing sites.

2. Need to move forward with a broader "process" for the Bay of Fundy with a design that brings various views and decision-makers to the table.

3. Bring all potential sites to the "table" at once for discussion and evaluation as a package; industry needs to know where they will be able to operate in the future, and this will provide a good basis for discussion.

4. Be precautionary by identifying sites to the best of present knowledge, or start with local information (TEK) for others, at the same time proceed with studies to verify decisions, and modify plan accordingly.

5. Put together the best possible network of MPAs from an ecological standpoint, and bring these out for discussion, without watering down for political reasons.

6. Think nodally, each small area being a node, joined together to form a system, and geographically distribute these small sites which in turn distribute out the socio-economic impacts.

7. DFO must consult with local groups but provide the public education and the science.

8. For the sake of protecting a critical area it is important to select the proper management tool, to ensure long-term objectives are met.

PAPER PRESENTATIONS

Session One

BAY OF FUNDY - SCIENCE AND TOOLS

Chair: Thierry Chopin, University of New Brunswick,
Saint John, New Brunswick

SHOREBIRDS, SNAILS, AND *COROPHIUM*: COMPLEX INTERACTIONS ON AN INTERTIDAL MUDFLAT

D.J. Hamilton[1,2] and A.W. Diamond[1]

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Semipalmated sandpipers (*Calidris pusilla*) migrate annually through the upper Bay of Fundy, feeding heavily on the amphipod *Corophium volutator* in intertidal mudflats. This region is a critical staging area for these birds; up to one million pass through the Bay each year. Typically an individual sandpiper spends approximately 2 weeks on the mudflats, eating several thousand *Corophium* per day. This intense predation may exert a strong top-down force on the *Corophium* population, and may have other indirect effects on the rest of the mudflat community. Predation by shorebirds is thought to be important in structuring this system.

Using predator exclosures and application of fertilizer, we examined both the top-down effect of predation by birds and the bottom-up effect of nutrient enhancement on the invertebrate community on an intertidal mudflat at Avonport, N.S. Because this is a simple community with one main predator and prey item, theory suggests that it may be an ideal system in which to observe a trophic cascade. We assessed this possibility, and examined whether nutrient addition enhanced the cascade, as has been suggested by some authors.

Beginning in mid-July, 1999, we erected 20 predator exclosures, measuring 1.2 x 1.8 m and designed to prevent birds from feeding within them, and 20 paired control areas in the mid-intertidal zone, approximately 500 m from the high water mark. We then randomly selected half of these paired sites and fertilized them using tree fertilizer stakes placed just below the surface of the sediment. We collected samples for invertebrate abundance and chlorophyll a concentration (as an index of diatom abundance) three times during the experiment - just after sites were set up, 3 weeks later, and again 3 weeks after that. These times correspond roughly to the period before shorebird arrival, at peak shorebird abundance, and just after departure of most birds. We also monitored abundance of mud whelks (*Ilyanassa obsoleta*) during sampling periods by counting whelks in each exclosure and control. We quantified bird abundance by estimating the percentage of exclosures and controls covered by footprints throughout the study.

Exclosures were reasonably effective, keeping out about 80 % of birds. Shorebird predation reduced *Corophium* abundance by more than 80 % by the end of the experiment, and effects were consistent in fertilized and unfertilized sites. The top-down effect did not transmit to the diatom level, as would be predicted under the trophic cascade hypothesis, and had little influence on other species in the system. Fertilizer significantly enhanced algal abundance mid-way through the experiment, but the effect disappeared later in the study, and the increase in diatom abundance did not lead to an increase in *Corophium*. Because effects did not cross trophic levels and our manipulations generated few indirect effects in the community, it appears that neither top-down nor bottom-up effects were of paramount importance. Transmission of effects through the system was probably blocked by the activities of mud whelks, which are competitors of *Corophium*. Whelks responded rapidly to both fertilizer application and bird predation; when either primary production increased or *Corophium* declined, *Ilyanassa* increased in abundance. Through a combination of interference and exploitation competition, whelks acted as compensating herbivores and, by blocking the trophic cascade and preventing transmission of indirect effects, probably contributed to the stability of the mudflat community.

These results demonstrate that, although trophic cascades tend to appear in simple communities, they are certainly not always present, even when there is strong and focused predation. It may be that the presence or absence of a compensating species is a more important predictor of cascading trophic interactions and community stability than is community complexity per se. If these results can be generalized to other locations within the Bay of Fundy, it is possible that, contrary to previous assertions, birds have little long-term effect on the intertidal community. While it is clear that Semipalmated Sandpipers need the upper Bay of Fundy as an annual staging ground, it is not clear that the mudflats need sandpipers, as has been previously suggested.

MODELING INITIATIVES IN THE BAY OF FUNDY

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Over the past years there had been an intense modeling effort in the Quoddy region to answer questions related to aquaculture. Now this effort is being expanded to include a model of the full Bay of Fundy and Gulf of Maine. A model with high resolution in the Grand Manan area will address aquaculture issues. A slightly different model of the Bay will investigate trends in mean sea level and changes in tidal range related to climate change and isostatic effects. This presentation will briefly review results from the Quoddy area modeling as well as plans and progress in the initiatives for the full Bay of Fundy.

SIMPLE BIO-ECONOMIC MODELING AS A PREDICTOR OF ESTIMATING HARVEST POTENTIAL AND ECONOMIC VALUE OF SOFT-SHELL CLAM (*MYA ARENARIA*) RESOURCES IN SOUTHWESTERN NEW BRUNSWICK, CANADA

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Soft-shell clam harvesting in Southwestern New Brunswick is of traditional and economic importance to Southwestern New Brunswick. There are presently 400 commercially licensed clam diggers, 150 of which harvest throughout the year (full-time harvesters). The clam industry is unique to the Bay of Fundy in that the Bay seldom sees ice unlike the Northern coast of the province. Therefore, harvesters are able to work for 12 months of the year, with exception to PSP (paralytic shellfish poisoning) closures during 4 to 8 weeks of the summer. Fish landing statistics maintained by Fisheries and Oceans Canada for the Atlantic coast severely underestimate the actual value of soft-shell clam resources. The primary causes of this problem are the inability to develop an accurate reporting plan for the industry and the lack of a resource management strategy for this species. Simple bio-economic modeling can be used as a predictor along with existing conventional data to better estimate the actual value of soft-shell clams by applying biological and harvesting capacity information as indicators.

LUNAR-POWERED AQUACULTURE: THE USE OF TIDAL PUMPING IN LAND-BASED FISH FARMS

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For centuries man has marveled at the magnitude, power, constancy and predictability of the tides in the Bay of Fundy. The concept of using tides to naturally pump water for land-based aquaculture has been proposed but to date, the concept remains a paper exercise. In effect, this lunar-powered aquaculture is a flow-through technology without pumps. Technically, the systems involved are simple, highly dependable, and virtually unaffected by mechanical failures, weather, predators or power outages. Tidal-based aquaculture retains all of the advantages of other land-based systems with few of the disadvantages. The economical advantages include relatively low capital investment, and low labour and operating costs. With tidal pumping, there is no need for large centrifugal pumps, costly intake systems, expensive water conditioning components, or large electrical backup generators. The cost of pumping water including pump backup and maintenance, is eliminated. Also eliminated is the cost of chilling water and climate control which are required with recirculation systems used for culturing cold-water species. Other advantages include: ease of effecting site security, facilitation of automation, and enhanced ability to control environmental factors. Tidal land-based aquaculture is highly environmentally friendly. The highly intensive nature of land-based aquaculture makes for a relatively small footprint. Current technology exists to concentrate, collect, store and dispose of solid wastes. The dissolved wastes can be removed from the water by introducing aquatic macrophytes such as rockweed or kelp into the collecting reservoir. Because escapment is not possible, there can be no chance for genetic "pollution" of wild strains. Similarly, the risk of introducing diseases into the environment is greatly reduced. Although several types of shoreline could be exploited, the physical constraints imposed by the technology together with the potential for negative environmental impacts limit the number of suitable sites.

This presentation will describe the concept of tidal pumping in land-based fish farms with specific reference to a proposal to grow halibut at a site in Passamaquoddy Bay. Particular emphasis will be given to the suitability and availability of sites and the overall potential for using this method.

HIGH RESOLUTION IMAGING AND TERRAIN EXTRACTION ALONG THE BAY OF FUNDY COASTAL ZONE, NOVA SCOTIA, CANADA

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The Bay of Fundy is surrounded by a variety of coastal zone conditions. COGS has recently been awarded an infrastructure grant by the Canadian Foundation for Innovation to support applied geomatics research along the coastal zone. In the fall of 1999 the Annapolis and Minas Basins were imaged by the airborne polarimetric synthetic aperture radar (SAR) system on board the Convair 580 operated by Environment Canada. The system operates in the C-band region of the spectrum in a quad-pole configuration HH, VV, VH, HV. The inter-tidal mudflats of the Minas Basin were exposed at low tide during the SAR acquisition. Radarsat extended high beam mode 6 was acquired within days of the airborne data for comparison to the polarimetric data. The SAR data will be used to interpret the type of shoreline (cliff, sand, etc.), landcover, and the coastal geology. Other remotely sensed data acquisitions are planned for the summer of 2000 including terrestrial airborne laser altimeter (LIDAR) and CASI. The LIDAR data will be used to build a digital elevation model (DEM) along the coastal zone and compare it to other sources. The CASI data will be used to interpret coastal geomorphology and bottom type in the inter-tidal zone. Other satellite data will image the area during the airborne campaign to be used for comparison as it relates to landcover and coastal information extraction. The high resolution DEM will be used to model storm surge events and predict what areas are susceptible to coastal flooding. Other inland applications include soil erosion modeling, watershed analysis such as water quality assessment, and geological mapping. This research ties in with several other land-based initiatives with southwest Nova Scotia and the datasets and results will be accessible on the World Wide Web.

THE USE OF GEOGRAPHIC INFORMATION SYSTEMS FOR COASTAL ZONE MANAGEMENT.
COBSCOOK BAY, MAINE. A CASE STUDY.

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Abstract

Determining the accurate length of the coastline is important for such coastal zone management applications as shoreline classification, monitoring erosion , mapping biological resources, habitat assessment, and for the planning and response to natural (*e.g.* storm surges) and manmade disasters (*e.g.* oil spills).

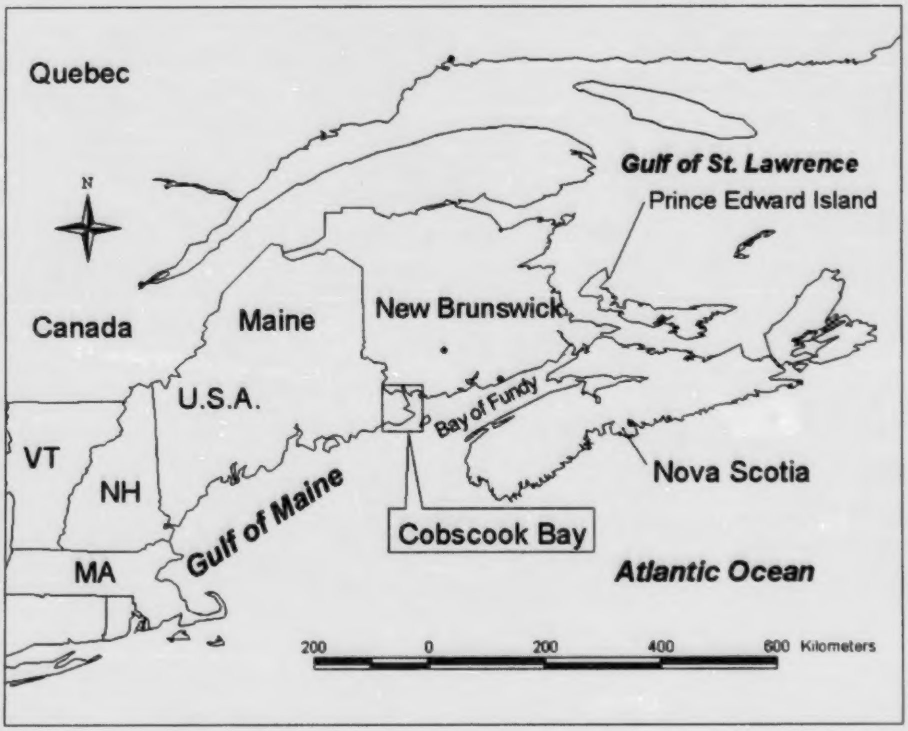
The increasing use of spatial data and GIS (geographic information systems) by organisations and researchers is a valuable tool for coastal zone management. The effectiveness of the results obtained by using a GIS is dependent upon the quality of the data that goes into these systems. This data is known as spatial data, since each geographic feature in the database has its own geographic coordinates such as longitude and latitude. Another important aspect of spatial data is that of scale. As with a map, spatial data contains geographic information that is limited to the scale of the database. For example, a 1:100,000 scale map does not show as much detail as a 1:50,000 scale map because it displays an area that is four times smaller. The reduction of detail on maps is known as map generalisation. Map generalisation not only limits the amount of information that can be shown on a map, but it can also limit the accuracy of a map. The same is true of spatial data. Spatial data is simply map data in a digital format.

This paper will demonstrate how five different types of spatial data produce different results for shoreline length, high water area, and the number of islands in Cobscook Bay, Maine.

Introduction

This paper is based on research that I have done for my MA Geography thesis at Carleton University in Ottawa. I am using Cobscook Bay, Maine as a case study to find out how different types of spatial data that are used by a GIS (geographic information system) can produce different results when used to measure various geographic features such as the shoreline of the bay, the shorelines of the islands that are within the bay, the number of islands of the bay, the area of the islands of the bay, and the water area of the bay at its mean high tide level. Cobscook

Bay is located in the Southeast corner of the American state of Maine. The bay consists of many coves, numerous smaller bays, and harbours. There are also many islands and rock ledges within Cobscook Bay. The two largest communities that border the bay are Eastport and Lubec, both of which have populations of approximately 2000 people.


Quebec
Gulf of St. Lawrence
Prince Edward Island
N
Canada
Maine
New Brunswick
U.S.A.
Bay of Fundy
VT
NH
Nova Scotia
Gulf of Maine
Cobscook Bay
MA
Atlantic Ocean
200
0
200
400
600 Kilometers

According to Jenson (1996), there are basically four types of spatial data: 1) Traditional Cartesian vector (sometimes know as spaghetti), 2) Topological vector, 3) Raster, and 4) QuadTree Raster. To get the most reliable results, it is necessary to use vector spatial data, since it provides a more accurate definition of line detail than raster spatial data can generally provide. The next requirement is to obtain vector spatial data at a scale and resolution that will produce accurate results. Small scale map data may be quite acceptable when geographic information is to be plotted on a regional map, but it is not adequate to accurately measure areas, and to calculate dimensions of geographic features. By its very nature, coastal planning and management is a process that involves many different map scales. The scale of the map data is often dependent upon the specific requirements and capabilities of individual planning and management organizations (Gaudet 1989).

For the GIS analysis of Cobscook Bay, I am concerned with the accurate measurement of the coastline, and therefore, it is important to determine a minimum acceptable scale that will be useful for that purpose. In 1991, Peter Wainwright along with the Canada Department of Fisheries and Oceans published a report titled "Fisheries Habitat GIS Strategy" and it contained recommendations for minimum scales for use in measuring shorelines and watersheds. This report described that a minimum acceptable scale to portray the coastline should be at 1:40,000 scales and larger, and that the minimum scale for watershed mapping should be at the 1:20,000 scale (Wainwright 1991). For the GIS analysis of Cobscook Bay, this 1:40,000 scale recommendation will be used as the desired minimum acceptable scale to measure the coastlines of the mainland and islands of the bay. For identification purposes, the best spatial data that is obtained that meets or exceeds this minimum requirement will be designated as the "baseline scale". The next step is to located other sets of spatial data that are of different scales, and then to use this data to measure Cobscook Bay. The results of the GIS analysis will be placed in a table so that the various measurements can be compared to the results that were obtained by the GIS analysis that used the "baseline" scale of 1:24,000.

Sources of GIS data that was used to measure Cobscook Bay

Cobscook Bay was analysed using ESRI's ArcView 3.2 geographic information system running on a 450 MHz Pentium III based microcomputer. The spatial data for the analysis was obtained as free downloads from the following Internet sites:

- Maine Office of GIS Internet site at http://apollo.ogis.state.me.us
- The United States Geological Service Coastline Extractor at http://crusty.er.usgs.gov/coast/getcoast.html, and
- The Pennsylvania State University's Maps Library site at http://ortelius.maproom.psu.edu/dcw/.

The spatial data from the Maine Office of GIS were downloaded as zipped ArcInfo (A GIS application made by ESRI) format files at scales of 1:24,000 and 1:100,000. The Maine Office of GIS organises their spatial data according to map layer features and to various types of coverage areas. Each type of spatial data is identified by a geographic name, an attribute (such as road or shoreline), and a map scale. The data were digitized from the Mean High Water (MHW) line as shown on USGS 1:24,000 scale quadrangle maps. The accuracy limits for the 1:24,000 scale data is that "not more than 10 percent of the points tested shall be in error by more than 1/30 inch, measured on the publication scale" for horizontal accuracy (ground scale) (USGS, Part 1, 1997, p.1.D-2) . The accuracy limits for the 1:100,000 scale data are that "at least 90 percent of points tested are within 0.02 inch of the true position" (ground scale) for horizontal accuracy (USGS, Part 3, 1997, pp. 3-12,3-13). The projection is UTM Zone 19. The horizontal datum is NAD83, and the units are in metres.

Note: The spatial data that is at the 1:24,000 scale is the best data that was obtained for this analysis since it falls well within the minimum 1:40,000 scale requirement. Therefore, the 1:24,000 scale spatial data shall be designated at the "baseline scale".

The spatial data that was obtained from the United States Geological Service Coastline Extractor were zipped Arc Ungenerate format files that can be used by the ESRI ArcInfo GIS program. The first set of data was in the form of NOAA/NOS Medium Resolution Digital Vector Shoreline at a scale of 1:70,000. This data was a portion of a larger data set that covers the entire United States of America. This data was digitized from NOAA nautical charts. The other set was a portion of the World Vector Shoreline which is at the 1:250,000 scale. This data can be used for world wide coverage. Both of these data sets only contain line information, and since no polygons are included with these data sets, only the lengths of features can be easily measured.

For the 1:70,000 data, the horizontal datum is NAD83, and the vertical datum is (NAVD29) which is based on the mean high or mean higher high shoreline position on published nautical charts. The spatial resolution of the data set is set to a minimum adjacent vertex spacing of five metres ground distance. The source of the spatial data are from the master copy of the National Ocean Service's coast charts, and they are supposed to meet or exceed National Map Accuracy Standards (Rohmann 2000).

The 1:250,000 data uses the WGS84 horizontal datum, and the horizontal accuracy requires that 90 % of all significant shoreline features are to be located within 500 metres (or 2.0mm at 1:250,000 map scale) circular error of their true geographic positions. The vertical datum is based on the mean high water mark designated MHW. The original source of this data is US Defence Mapping Agency now known as the National Imagery and Mapping Agency or NIMA (Soluri and Woodson 1990).

The spatial data from the Pennsylvania State University's Maps Library site was also in the form of zipped ArcInfo format files, but it was downloaded as one single file that covered the entire state of Maine. This spatial data was a portion of the Dataset from the larger spatial Dataset that is known as the Digital Chart of the World or DCW. The scale of the DCW spatial data is 1:1,000,000. Elevation datum is Mean Sea Level (MSL). The horizontal datum is WGS84, and the horizontal accuracy, "at a 90 percent confidence level for circular error, ranges from 1,600 feet to 7,300 feet." (Environmental Systems Research Institute, Inc. 1993, p. 2-13).

The boundary and extent of Cobscook Bay is also not agreed upon by various people and organizations who are familiar with the area and there are at least three definitions of its geographic limits. All of the three definitions of Cobscook Bay include all of the inner bays and extend to the following limits:

- Comstock Point to Shackford Head.
- Comstock Point to Estes Head.
- Estes Head to the town pier in Lubec, Maine.

Therefore, to make this analysis as thorough as possible, all three boundaries of Cobscook Bay were measured using the spatial data that was obtained for this study. The results of this analysis are listed in three tables in the conclusion of this paper.

GIS analysis of Cobscook Bay, Maine

The same basic methodology was used on each set of spatial data to obtain the various measurements of the lengths of shorelines, and the areas of the three different Cobscook Bay limits. The first step was to convert the spatial data into an ArcView shapefile, and then to load the shapefile into the ArcView GIS. The next step is to change the projection to a UTM (Universal Transverse Mercator) projection. The use of the UTM projection was selected so that metres could be used as the measuring unit, and to have consistency between the various types of GIS data. The UTM zone was set to zone 19 which covers the area of Maine, and the map's horizontal datum was set to NAD83. The UTM projection's properties allow it to accurately represent smaller shapes, and at the same time, with a minimal distortion of larger shapes within the zone. Local angles are also true within each zone.

Next, the data was matched to the same geographic limits of Cobscook Bay. This was accomplished by a technique known as the clip theme operation, or sometimes it is known as the "cookie cutter approach". A template that matches the limits of Cobscook Bay is created, and then saved as a polygon shapefile. This template is used to cut away the excess spatial data from the selected spatial data set, and the output is saved as a new ArcView shapefile. This technique works for both line and polygon data. Point data can also be selected using a theme on theme selection process, or by using the geoprocessing wizard that comes with ArcView 3.2. An ArcView programming script called "calcapl.ave" is run on the new spatial data for the purpose of recalculating the lengths, areas and perimeters of geographic features. The results of these operations are then saved in their associated database tables. If these new measurements are not made, then the dimensions of the geographic features will be based on their previous extents. The end result is a new set of spatial data that contains tables and spatial coordinates that match the specified limits of Cobscook Bay. This operation is run three times so that the three limits of Cobscook Bay can be measured. Control points that represented the three limits of Cobscook

Bay were established on the 1:24,000 scale GIS files of Cobscook Bay (the largest and most accurate set of spatial data). Their UTM coordinates were obtained by running a program script called "addxycoo.ave", and these control points were then copied to the other four scale-based sets of GIS files. In this way, the templates that were used to create the new data sets for each scale of GIS data used the same control point (based on UTM coordinates) on each map.

The new sets of spatial data can be used to find the lengths of shorelines and areas of water bodies and islands of Cobscook Bay, Maine. This geographic information can be obtained by several methods such as using a query function in the corresponding map tables, or by selecting the features on the screen and going back to the tables to see the results.

The following are the results of this spatial analysis of Cobscook Bay. The scales of the spatial data are listed on the top row, and the type of GIS analysis that was performed is listed in the far left column.

Dimensions of Cobscook Bay, Maine, USA.

Comstock Point to Shackford Head.

	1:24,000 **Baseline Scale**	1:70,000	1:100,000	1:250,000	1:1,000,000
Length of Mainland Shoreline	357,856.5 Metres	315,816.5 Metres	299,445.9 Metres	192,493.9 Metres	168,850.6 Metres
Length of Island shorelines	57,482.0 Metres	51,674.5 Metres	31,786.8 Metres	20,884.8 Metres	0.0 Metres
Number of Islands	169	87	29	10	0
Area of Cobscook Bay	89,946,702.67 SQ. Metres	N/A	90,197,323.7 SQ. Metres	N/A	94,019,162.5 SQ. Metres
Area of Islands in Cobscook Bay	2,404,855.7 SQ Metres	N/A	1,962,162.4 SQ Metres	N/A	0 SQ Metres

Dimensions of Cobscook Bay, Maine, USA.

Comstock Point to Estes Head

	1:24,000 **Baseline Scale**	1:70,000	1:100,000	1:250,000	1:1,000,000
Length of Mainland Shoreline	363,499.8 Metres	321,249.2 Metres	304,562.3 Metres	198,361.3 Metres	171,969.8 Metres
Length of Island Shorelines	57593.0 Metres	51,674.5 Metres	31,786.1 Metres	20,884.8 Metres	0.0 Metres
Number of Islands	171	87	29	10	0
Area of Cobscook Bay	92,070,024.6 SQ. Metres	N/A	92,297,119.9 SQ. Metres	N/A	95,991,319.6 SQ. Metres
Area of Islands in Cobscook Bay	2,405,224.3 SQ.Metres	N/A	1962162.4 SQ.Metres	N/A	0.0 SQ. Metres

Dimensions of Cobscook Bay, Maine, USA.

Estes Head to Lubec Town Pier

	1:24,000 **Baseline Scale**	1:70,000	1:100,000	1:250,000	1:1,000,000
Length of Mainland Shoreline	380,900.4 Metres	335,820.5 Metres	317,125.4 Metres	220,612.8 Metres	180,019. Metres
Length of Island Shorelines	60,860.7 Metres	55,709.6 Metres	35,737.4 Metres	25,917.6 Metres	1,223.8 Metres
Number of Islands	186	95	33	13	1
Area of Cobscook Bay	100,536,850.3 SQ. Metres	N/A	100,534,727.2 SQ. Metres	N/A	105,004,515.8 SQ. Metres
Area of Islands in Cobscook Bay	2,639,025.3 SQ. Metres	N/A	2,181,156.5 SQ. Metres	N/A	201,450.4 SQ. Metres

Conclusion

Several things are quite evident from the above tables. As the scale of the maps and spatial data decreases, so does the length of the shorelines of the mainland and of the islands. This is due to the decrease in spatial resolution and the amount of generalization of geographic detail that occurs as the map scale becomes ever smaller. On the other hand, the water area of Cobscook bay tends to increase in size as the scale gets smaller. This is due to the elimination of smaller geographic features such as islands which by default, will create more open water area. The number of islands decrease quite rapidly as the scale becomes smaller. The generalization of geographic features can also create more open areas or, it can sometimes reduce the amount of open water area if the land area is generalized over a water area. As can be seen from the tables, the size of a geographic feature that is measured using spatial data in a GIS becomes more precise as the scale becomes larger and less precise when the scale becomes smaller. Small scale maps are fine for the depiction of geographic information that covers a large area. When accurate measurements of geographic features are required, then a minimum acceptable scale must be established so that a higher degree of precision can be obtained. The scale of the spatial data should also be included as part of the GIS analysis for reference purposes.

Note: A larger version of this paper is available on my home page at http://www3.sympatico.ca/mkostiuk/gis4czm.

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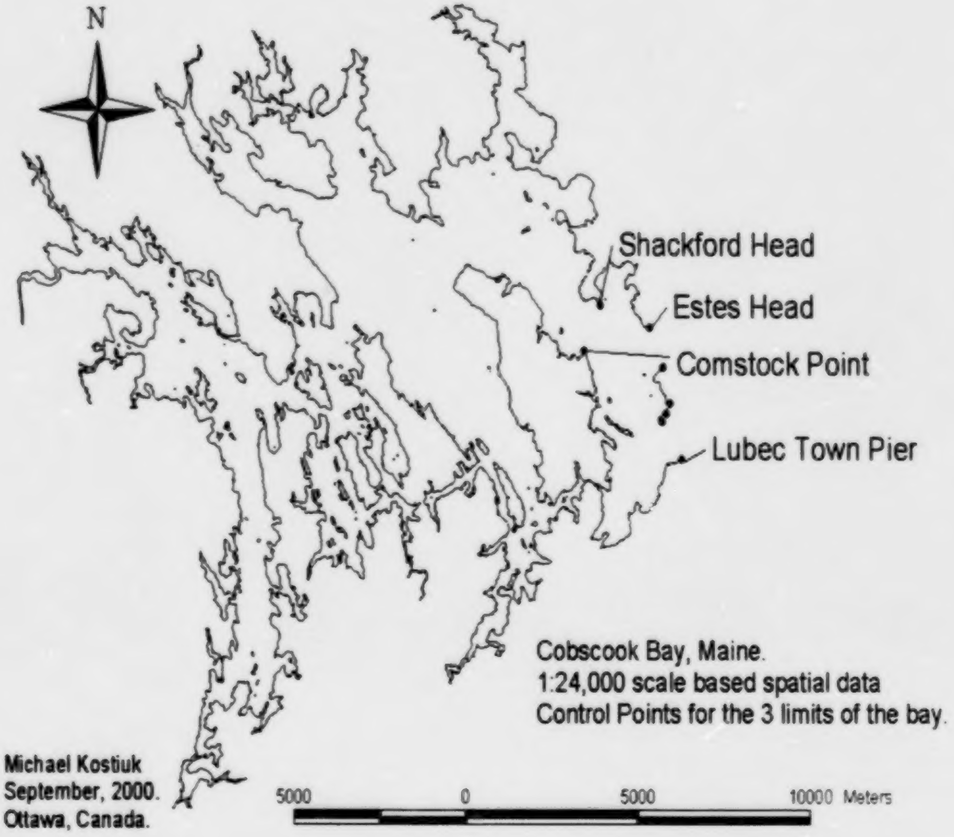
N
Shackford Head
Estes Head
Comstock Point
Lubec Town Pier
Cobscook Bay, Maine.
1:24,000 scale based spatial data
Control Points for the 3 limits of the bay.
Michael Kostiuk
September, 2000.
Ottawa, Canada.
5000
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5000
10000 Meters

Session Two

COMMUNITIES, CONTAMINANTS AND HABITATS

Chairs: Thierry Chopin, University of New Brunswick,
Saint John, New Brunswick
Peter Wells, Environment Canada, Dartmouth,
Nova Scotia

A MARINE ENVIRONMENTAL QUALITY (MEQ) FRAMEWORK AND THE BAY OF FUNDY

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The Bay of Fundy is a tidal coastal embayment of the Gulf of Maine, is well studied, has valuable living resources, and is currently the focus of much attention related to coastal issues and community involvement in integrated coastal management. Canada passed the Oceans Act in 1997. One section of the Act addresses the requirement for a comprehensive set of marine environmental quality (MEQ) guidelines, objectives and standards for estuaries, coastal waters and the offshore of Canada. This would presumably build upon existing guidelines and standards which have been in place in Canada for many years (*e.g.* coliform bacteria and algal toxins in shellfish waters and shellfish, trace contaminants in dredging spoils, toxic substances in industrial effluents) but which developed in an *ad hoc* fashion. A broad conceptual framework would guide the comprehensive and coordinated approach to MEQ in the Oceans Act context, acknowledging prior legislation and work. This study developed such an MEQ Framework, based in part on knowledge and management needs of the Bay of Fundy. The MEQ Framework has 6 primary components (research; criteria or the knowledge base; establishment of priorities; assessment; guidelines, objectives and standards; and monitoring and surveillance). This framework was tested for three stressors in the Bay of Fundy - paralytic shellfish poisoning (PSP) (a marine toxin), PCBs (synthetic chemicals) and mercury (from both natural and industrial sources). The framework proved useful in organizing information and evaluating the chosen stressors. The study illustrated that MEQ guidelines, objectives and standards for such priority substances and parameters are required for the protection and conservation of ocean and human health in Canada. The MEQ Framework, in the context of the Bay of Fundy, is presented for comment and review.

BEYOND ENVIRONMENTAL MANAGEMENT: THE WIDER COMMUNITY OF PARTICIPATORY DESIGN, SOCIAL SCIENCE AND PROFESSIONAL PLANNING

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Ocean and coastal space is rapidly being defined, limited and patterned by ownership, rights of use and natural reserves. An emergent set of management techniques is becoming established in coastal, near shore, and ocean environments without considering the inclusion of non-science disciplines. Instead, the planning of oceans and coasts must connect with land-based tradition and spatial practice designing for human activity rather than simply managing it.

This paper reports on the initial stages of a research project, partly funded by the Government of Canada, to investigate the relationship between community, science, and management. This paper argues that the fundamentals of architecture and planning are necessary to effective integrated environmental management and proposes some ways to involve architects and planners in the coastal zone. The managerial discourse, whether it be environmental, governmental, economic, industrial, is just one set of appropriate organizing techniques. A mentality of design, and the skills of the professional planner, must be added to that of management to help plan the expanding occupation of our oceans and coastal spaces. The addition of design to current management techniques will forge links between land and ocean space and represent cultural values in a predominantly political and scientific dialogue.

Design professionals can contribute to planning coastal and ocean areas by adding their analytical and synthetic techniques, by including social and cultural issues in a broad, practice-based, critical framework, and by voicing their independent and legally mandated concern for the public good. Experience on land argues for 'community voice' in ocean planning - one that relates design and management, urban and ocean spatial practices, and past experience with contemporary situations.

THE MARINE FOOD WEB IN RELATION TO THE MOVEMENT AND ACCUMULATION OF TOXINS IN SAINT JOHN HARBOUR, NEW BRUNSWICK, CANADA

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The purpose of this study was to establish baseline measurements of tissue contaminant levels and biometric measurements of the indigenous biota of the Saint John Harbour, New Brunswick, Canada. Five intertidal organisms (*Ascophyllum nodosum, Fucus vesiculosus, Littorina littorea / L. saxatilis, Gammarus oceanicus* and *Mytilus edulis*) were studied at six locations in the Harbour between August, 1994 and September, 1995. In general, the results demonstrated relatively low tissue contaminant levels and no strong correlations between tissue contaminant levels and the biology of the organisms. Copper, lead and zinc contamination reflected the pattern of municipal sewage outfalls and copper was especially high in samples from some areas. Significantly higher cadmium levels were detected in the biota from the sites in the western part of the Harbour. Polycyclic aromatic hydrocarbons were higher in the central Harbour sites and may be causing adverse biological effects. No organochlorinated pesticides and low polychlorinated biphenyls in the tissues of the biomonitors reflected the reduced impact of those contaminants. Unique flushing conditions in the Saint John Harbour have probably prevented extensive local contamination. The patterns of significant differences among the sample locations and seasons demonstrate that conditions are degrading, however Saint John has the opportunity to recognize this degradation and address it before the ecosystem becomes permanently damaged.

LETANG INLET: LONG TERM FAR-FIELD MONITORING AND ASSESSMENT OF BENTHOS IN AN AREA WITH NUTRIENT LOADING

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This study was undertaken over five years (1994-1999) to evaluate embayment-wide impacts on the benthic fauna in two areas with intensive salmon net-pen aquaculture (Lime Kiln Bay, Bliss Harbour). A third embayment (Deadmans Harbour), which lacked significant aquaculture activity, served as a reference site. Changes in benthic community structure were investigated using multivariate, distributional and univariate analyses because these alterations reflect cumulative stresses from various sources, ranging from organic enrichment to chemical therapeutants. Changes in the benthic community structure at the Deadmans Harbour reference site indicated a general improvement in ecosystem quality during the study period. Lime Kiln Bay experienced an increase in aquaculture activity during the study period followed by a complete cessation in 1998. Analyses supported that major environmental alterations did take place in Lime Kiln Bay, as evidenced by increased biological stress on the benthic community. A significant decline in diversity with a corresponding significant increase in enrichment, measured as organic carbon, occurred between 1994 and 1995. Analysis of indicator species corroborated the enrichment trend. Sedimentary microbial biomass and carbon concentrations decreased from 1997 to 1999, reflecting the cessation of fish farming in the area, but recovery of the benthos to initial levels did not take place during this time. It is concluded that the embayment-wide benthic impact measured within Lime Kiln Bay in 1995 persisted until 1999 even though organic loading decreased. Unlike Lime Kiln Bay, enrichment levels in the Bliss Harbour aquaculture area were elevated at the onset of the study, resulting in high impact throughout the study period. The observed differences in community structure within the three embayments were not attributable to differences in sediment types, temperature, salinity or water depth.

ESTUARY + CAUSEWAY = SPECIES, POPULATIONS AND HABITATS LOST IN THE PETITCODIAC RIVER

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The Petitcodiac Causeway was built in 1968 as a transportation link between Moncton and Riverview, New Brunswick. Physical and chemical changes to the former Petitcodiac estuary include (1) the conversion of approximately 21 km of brackish macro-tidal river into a freshwater non-tidal reservoir, (2) the physical obstacle to migrating fishes posed by the causeway, which is only partly remediated by vertical-slot and surface-port fishways, (3) truncation of the tidal prism of the estuary, and elimination of the estuarine "salt wedge" (the portion of the estuary where a layer of fresh water overlies a layer of salt water), which is normally an important nursery habitat for anadromous fishes, as well as a transition zone for osmoregulatory and thermal acclimation, (4) massive sedimentation below the causeway, reducing the width of the river from 1 km in 1968 to 80 m by 1998. Almost immediately, spawning migrations of anadromous fishes were reduced or eliminated. Repeated attempts to improve the effectiveness of the fishways were unsuccessful, largely due to a combination of powerful tides and high concentrations of suspended sediment.

In response to concerns expressed by conservation organizations and government natural resource departments, a Trial Gate Opening Project was initiated in 1997 to investigate the feasibility of restoring estuarine conditions above the causeway. However, changes have been opposed by a local group which asserts that the impoundment, or "Lake Petitcodiac", supports a valuable and stable ecosystem. Until recently, very limited data have been available for evaluation of this viewpoint. Within the context of the Trial Gate Opening Project, the freshwater impoundment was intensively studied over three years, 1997-99. Data on fish, planktonic and benthic invertebrates, and macrophytes were collected. This paper summarizes major results of the study.

Almost half the fish species formerly recorded from the freshwater portion of the river are diadromous, and most have been adversely affected by the causeway. Anadromous species whose populations have been greatly reduced (**r**), or eliminated (**e**), from the system include Atlantic salmon (*Salmo salar* **e**) (part of the genetically distinct Inner Bay of Fundy stock), American shad (*Alosa sapidissima* **e**), sea-run brook trout (*Salvelinus fontinalis* **r**), tomcod (*Microgadus tomcod* **e**), striped bass (*Morone saxatilis* **e**), and rainbow smelt (*Osmerus mordax* **r**). American shad probably served as the host for the glochidia of the dwarf wedgemussel, *Alasmidonta heterodon*, which is now listed as extirpated in Canada and endangered in the U.S.A. The Petitcodiac River was the only known Canadian location of *A. heterodon,* which was described as "common" in the river in the decade preceding causeway construction. We conclude that the causeway was the direct cause of the extirpation of this unique northern population, by excluding the glochidial host from the system, thus interrupting the mussel's life cycle.

Benthic and planktonic communities of the headpond are depauperate, and the species composition is typical of a strongly disturbed ecosystem. Most taxa are marine/estuarine in origin, or belong to freshwater groups with rapid dispersal. The headpond is subject to intrusion of salt water via the fishway and frequent water level fluctuations. Water temperature regularly exceeds 25 °C in the summer, a thermal regime which is not well tolerated by many of the native fishes. Illegally introduced warm-water species (smallmouth bass *Micropterus dolomieui* and brown bullhead *Amiurus nebulosus*) have flourished and are spreading to riverine parts of the watershed. Chain pickerel (*Esox niger*) has also been illegally introduced but to date has not spread to the extent of the other two species.

The majority of negative effects of the causeway are reversible, but several may not be, *e.g.* species extirpations and introductions.

At the time of writing (September 2000), the future of the watershed is uncertain. The Trial Gate Openings planned for 1998 and 1999 were not able to proceed because of inability to use the spring runoff to flush accumulated mud from the vicinity of the gates, so that the agreed-upon parameters of the experiment could not be achieved. In 1998, this was the result of a delay caused by a court challenge, and 1999 was a year with very little spring runoff.

Based on our three years of study of the freshwater environment, we predict the following:

- If the gates are opened or causeway is partially replaced by a bridge
    - improvements in the runs of anadromous fish species will occur almost immediately (but some unique genetic material, such as the Petitcodiac strain of Atlantic salmon, is gone forever)
    - the river channel will partially re-establish
    - salt marsh will develop on the shallow flats of the present headpond
    - the introduced smallmouth bass will continue to expand its distribution throughout the freshwater portions of the river, but the populations of introduced brown bullhead and chain pickerel may crash with the loss of the headpond.

- If the gates are not opened (*status quo*)
    - continued loss of anadromous fish species
    - increased populations of invaders (both plant and animal)
    - continued sedimentation and infilling (both above and below the causeway)

- shallow areas will become choked by weeds, and within decades the impoundment will become a freshwater marsh with a narrow river channel.

In closing, we note that in terms of ecosystem values, there are only a handful of macro-tidal estuaries in the world, whereas there are millions of small, shallow impoundments supporting centrarchids, esocids, cyprinids, alosids and ictalurids, in North America alone.

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THE EFFECTS OF AZAMETHIPHOS ON SURVIVAL AND SPAWNING SUCCESS IN FEMALE AMERICAN LOBSTERS (*HOMARUS AMERICANUS*)

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In southern New Brunswick, Canada, the salmon aquaculture has rapidly expanded to a $140 million industry. Recently the caged salmon have experienced infestations of sea lice. "Bath" treatments of the organophosphate pesticide, azamethiphos are used to treat the sea lice infestations. The period of sea lice infestations are coincident with spawning of the American lobster (*Homarus americanus*). Salmon aquaculture sites and lobster nursery areas share the same water, resulting in a situation in which lobsters may be exposed to effluent from sea lice treatments.

Preovigerous female American lobsters (N = 72) were divided into two treatment and one control groups. Ovarian maturation and spawning was induced using elevated water temperature and long day length. Lobsters were exposed four times for one hour to either 10 or 5 µg/L of azamethiphos. These concentrations represent 10 and 5 % of the recommended treatment concentration. Treatments were separated by two weeks and three experiments were conducted over three spawning seasons.

Survival and success of spawning were monitored. Similar results were observed in the three experiments. For example, in the second experiment, only one lobster was dead after the third exposure to10 µg/L azamethiphos, but after the fourth exposure, 43% (10) of the lobsters had died. In contrast, only 8% (2) of those exposed to 5 µg/L died after the final treatment and there were no deaths amongst the controls. In a separate experiment the activity of acetylcholinesterase (AChE) in the muscle of exposed lobsters was measured. These data suggested a possible cumulative inhibition of this enzyme. Alternatively, increased sensitivity of the lobsters during the fourth treatment compared to earlier treatments may be related to seasonal differences in physiology or to the endocrine state of preovigerous and spawning females.

Two months after the last treatment, spawning success, as assessed by the presence of extruded eggs, was also affected by exposure to the highest concentration of azamethiphos. Seven (54%) of the surviving lobsters exposed to 10 µg/L failed to spawn, while 2 (9%) of the surviving lobsters exposed to 5 µg/L of azamethiphos and only 1 (5%) of the control lobsters failed to spawn. Oocyte vittelin was resorbed by some of the lobsters in the azamethiphos treated groups.

HIGH COPPER CONTAMINATION IN LOBSTER FROM THE INNER BAY OF FUNDY AND SAINT JOHN HARBOUR, CANADA

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Lobsters and sediment samples were collected from various sites in the Inner Bay of Fundy and Saint John Harbour in 1999. Surprisingly, copper values in lobster digestive glands were conspicuously elevated: Cobequid Bay (CBY, 856 µg/g wet wt.), Cumberland Basin (CMB, 836 µg/g), and Shepody Bay (SHB, 637µg/g), followed by Minas Basin (MIB, 405 µg/g), Saint John Harbour (SAJ, 317 µg/g), and Minas Channel (MIC, 110 µg/g). These values, 10-80 times higher than in lobsters from non-industrialized sites such as Pubnico, Nova Scotia (Chou *et al.* 1998) are the highest ever reported in the Maritimes Region, Canada (Chou and Uthe 1978). Zinc concentration in Minas Basin lobster (129 µg/g) was 3 times higher than the relatively constant levels observed in other Maritime lobsters. Silver and cadmium were also elevated at all sites. An obvious trend in the geographical distribution of copper in lobster was observed: highest levels in lobsters from the Inner Bay and lowest levels in those collected from deeper, more open waters. There were no relationships between lobster metals and sediment concentrations. Sediment concentrations were within normal background levels compared with other Maritime surveys. The contributing source(s) of copper has not been identified. Lobsters from the Inner Bay can withstand and concentrate extremely high copper levels and may reach an upper limit beyond which it becomes adverse and ultimately toxic with negative consequences for the lobster stock. The possibility of uptake from diet and the source of discharge needs furthur investigation.

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DIOXINS/FURANS AND CHLOROBIPHENYLS IN *MYTILUS EDULIS* FROM THE GULF OF MAINE

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Since 1996, the Environmental Quality Monitoring Committee of the Gulf of Maine Council on the Marine Environment has collected data on levels of polychlorinated dioxins and polychlorinated furans and toxic PCB congeners (chorobiphenyls) in the Gulf of Maine/Bay of Fundy as part of its Gulfwatch monitoring programme. The programme uses blue mussels (*Mytilus edulis*) as a sentinel species for habitat exposure to chemical pollution. Sixty sites in coastal waters of the five US and Canadian jurisdictions in the Gulf have been sampled for dioxin/furans and chlorobiphenyls as well as other chemical pollutants. Toxic equivalent concentrations (TEQs) for these cytochrome P4501A-dependent EROD inducers have been calculated using international toxic equivalency factors. The data set that has been compiled provides a unique and valuable profile of these toxic chemicals in our regional coastal waters. This presentation will discuss levels and geographic distribution of these pollutants, as well as those of polyaromatic hydrocarbons (PAHs), in mussels from the Gulf of Maine and the significance of mussel contaminant concentrations to environmental and human health in the Gulf.

STRATEGIES FOR A SUSTAINABLE MANAGEMENT OF THE BROWN SEAWEED *ASCOPHYLLUM NODOSUM* (ROCKWEED)

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The harvest of the brown seaweed *Ascophyllum nodosum* has increased steadily during the last 10 years due to new market development. As a result, the harvest of rockweed has expanded into new areas along the Atlantic shore of Canada and the USA. The seaweed industry is an important component of the local economy as it provides jobs for hundreds of people along the shores of Nova Scotia and New Brunswick. However, recent collapses of some important fisheries in Atlantic Canada have created a strong public concern regarding management policies for marine resources. Rockweed plays an important role as habitat for several commercial and non-commercial species, consequently, a precautionary approach has been urged for this resource. Though the harvest of rockweed in Atlantic Canada is relatively new compared with the industry in Europe, its management has been highly dynamic during its 30 years of existence. In the late 1960's, marine plant management was either a "laissez-faire" or based only on single species resource sustainability. In the late 80's, the harvest of rockweed included area based management, licensed areas and tool regulation. In the late 90's, the pressure has been put to manage this fishery under a more conservative approach. The goal is to either make no significant changes in habitat structure or to keep impacts short-term and within limits that could be mitigated. The strategy to keep an economically viable industry within this new management approach is discussed here.

USE OF MESOCOSMS FOR MONITORING IN COMPLEX ESTUARINE ENVIRONMENTS: A CASE STUDY FROM THE SAINT JOHN HARBOUR, BAY OF FUNDY

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Estuaries are highly productive environments that maintain complicated and essential food webs. They also act as conduits for anthropogenic inputs into the marine environment from terrestrial and riverine sources. The Reversing Falls (RF) area of the Saint John Harbour (SJH) receives various discharges, including effluents from a pulp mill and a paper mill, wastes from several light industries, and treated and untreated sewage. Because of the complexity of this estuarine environment, it is difficult to identify the potential effects of point source discharges on aquatic biota. Although mummichogs (saltwater minnows; *Fundulus heteroclitus*) caged at RF and compared to those at a reference site (Black River) in 1995 and 1996 showed some site-specific reproductive endocrine effects, it was impossible to determine any cause-effect relationships with specific discharges. A portable, field-based artificial stream (mesocosm) system, however, has proven itself to be a viable alternative for assessing discharge effects at Reversing Falls. In 1997 and 1998, mummichogs were exposed in the mesocosm system to environmentally-relevant concentrations from the pulp mill located at Reversing Falls. Use of the mesocosm established that process changes in the mill between 1997 and 1998 improved effluent quality in regard to fish reproductive status. Determining the improvement in effluent quality using traditional field monitoring techniques would have been impossible due to the confounding effluents and complex water flow patterns at the site. More work is required at RF and the SJH to determine the cumulative effects of anthropogenic inputs on their estuarine and marine environments.

Session Three

SALTMARSHES AND RESERVES

Chair: Jon Percy, Clean Annapolis River Project,
Granville Ferry, Nova Scotia

TWO CENTURIES OF WETLAND PLANT COMMUNITY VARIABILITY IN BAY OF FUNDY SALT MARSHES: A PALEOECOLOGICAL STUDY

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Salt marshes are coastal ecosystems located in a zone of transition between terrestrial and marine environments. It is generally accepted that higher elevations, dominated by *Spartina patens*, accumulate sediment in such a way as to 'keep pace' with sea level rise are termed 'stable'. Marsh sediments contain pollen, which provides a detailed record of vegetation. Pollen records have been used to trace past sea level as changes in marsh vegetation are often assumed to be a direct function of changes in sea level. However, in a stable salt marsh, can other variables, besides sea level rise, explain changes in the wetland community? Previous studies in other salt marshes have shown that marsh vegetation changed as a result of fluctuations in the physical environment, however such studies have been done on decadal scales and a finer resolution study has yet to be undertaken.

We are using pollen analysis to reconstruct marsh community changes over the last 200 years in selected Bay of Fundy salt marshes. Accumulation rates have been calculated from dated sediments and comparison with local tide gauge records suggest that these systems are presently 'keeping up' with local changes in relative sea level, thus implying 'stability'. Marsh community variability is reconstructed at a 5-year resolution. Profiles of regional variability in temperature and precipitation over the last two centuries provide a framework in which to pose the question, 'is the wetland community in these marshes responsive to climate change?'

CONSERVATION OF WILDLIFE HABITAT IN THE AGRICULTURAL LANDSCAPE OF THE TANTRAMAR DYKELANDS

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The Tantramar dykelands, located on the Chignecto Isthmus at the head of the Bay of Fundy between the provinces of New Brunswick and Nova Scotia were once a vast expanse of salt marsh. Draining, dyking and crowning of this land has occurred since the late 1600's, drastically altering the Tantramar landscape. In 1996, the New Brunswick Department of Natural Resources and Energy in cooperation with the Canadian Wildlife Service and Wildlife Habitat Canada initiated a project to develop a cooperative wildlife habitat strategy for the Tantramar dykelands. This project forged partnerships between wildlife agencies, stakeholders and landowners and led to the development of a land use strategy that focused on incorporating wildlife habitat conservation into the agricultural landscape of the dykelands.

Since the development of the Strategy, this project has progressed into an implementation phase where key wildlife habitat is being secured through conservation techniques that are based on principles of integrated land use. Specific projects include riparian management, small wetland enhancement and the promotion of best management practices in agriculture. Completion of the project will involve the establishment of a framework for community involvement to ensure wildlife habitat conservation remains an important priority in land use planning decisions in the Tantramar dykelands.

AN ASSESSMENT OF ARCVIEW 3.1 AND IMAGE ANALYSIS 1.0 AS TOOLS FOR MEASURING GEOMORPHIC CHANGE AT THREE BAY OF FUNDY SALTMARSHES

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A study was conducted at three saltmarsh sites in the upper Cumberland Basin, Bay of Fundy, to assess change in saltmarsh margin and tidal creek location over approximately a 60 year period. This was achieved by overlaying digitized representations of coastal features derived from standard aerial photographs that were rectified using ESRI's ArcView 3.1 and ESRI/ERDAS's Image Analysis 1.0 software. The purpose of the study was to evaluate the capabilities, limitations, advantages and disadvantages of using ArcView 3.1 and Image Analysis 1.0 as tools for creating and using rectified images to assess temporal and spatial change in a coastal environment. It was discovered that all photographs for this region could be rectified with a total error of 5.5 m or less and that ArcView 3.1 and Image Analysis 1.0 are effective tools for assessing environmental change at broad spatial and temporal scales. A number of interesting trends in saltmarsh evolution were discovered that warrant further investigation. Therefore, these tools are likely to be useful and cost effective for other studies with similar image quality requirements.

ANNUAL AND SEASONAL VARIATIONS IN EROSION AND ACCRETION IN A MACRO-TIDAL SALTMARSH, BAY OF FUNDY

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This paper presents results from a field study on the controls on the sediment budget of Allen Creek Marsh in the upper Cumberland Basin. Annual and seasonal variations in sediment accretion on the marsh surface and erosion at the marsh margin cliff were measured from 1996 - 2000. Changes in surface elevation were derived from measured depths to buried aluminum plates and SET data. Margin erosion and expansion were measured using differential GPS.

Erosion and accretion vary both temporally and spatially. Seasonally, the highest rates of surface elevation change over the entire marsh occurred during the fall months (0.15 – 0.24 cm•month^{-1}). On an annual basis, higher annual rates of sediment accretion were measured (1.6 cm•a^{-1}) on the marsh surface during the 1996-97 year than either 1997-98 or 1998-99 which had rates of 0.6 cm•a^{-1} and 0.8 cm•a^{-1} respectively. This may be attributed to a larger number of ice blocks on the marsh surface during the winter of 1996-97 compared to the milder winters of 1997-98 and 1998-99. The mean rate of margin erosion was twice as high in 1996-97 (1.1 m•a^{-1}) than in 1997-98 (0.52 m•a^{-1}). Spatially, the highest rates of sediment deposition were observed in the high marsh over the 1997 winter season from ice inputs with minimal deposition in the low marsh.

Although the rate of vertical growth of the marsh surface exceeds the rate of relative sea level rise (0.3 cm•a^{-1}), erosion of the marsh margin cliffs is decreasing the overall surface area of the marsh available for deposition. As a result, predicting marsh sedimentary status based on SET and marker horizon data alone is insufficient to predict marsh survival under conditions of rising sea level.

TAKING THE TIME TO GET IT RIGHT: COMMUNITY-BASED SALT MARSH RESTORATION WORK IN NOVA SCOTIA

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Historically, large areas of salt marsh throughout the Gulf of Maine have been lost as a result of coastal developments. The community-based salt marsh restoration project is an attempt to reverse this trend through restoration of a demonstration site in the Canadian Gulf of Maine. The Ecology Action Centre in Halifax has received support under the North American Free Trade Agreement (NAFEC) programme to coordinate a project in which community and environmental interests are working in partnership with government agencies and other technical experts to restore and monitor a degraded salt marsh on the Nova Scotia side of the Bay of Fundy.

This project will increase the area of salt marsh habitat around the Bay of Fundy and serve as a demonstration site for similar community-based salt marsh restoration projects in the region. The project began in October 1999 by developing a list of biophysical, social and community factors for the identification, classification and selection of potential sites. The team is currently finalizing site selection through a series of community consultations to identify a community partner with whom to share resources and experience. Most importantly, one of the decisions made was to not rush the process; it is essential to take the necessary time to build trust and alleviate the concerns of local landowners and residents. Otherwise there will not be the necessary support for the project to be successful.

MOVING TOWARDS A COASTAL BIOSPHERE RESERVE IN ATLANTIC CANADA SOME LESSONS FROM THE SCOTIAN COASTAL PLAIN[1]

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Abstract

The UNESCO biosphere reserve concept has been proposed as an approach to the conservation and sustainable management of coastal areas in Atlantic Canada – specifically southwestern Nova Scotia and the Bay of Fundy. A preliminary assessment of the feasibility of developing the concept in coastal southwestern Nova Scotia concluded that the area meets the international criteria for biosphere reserves; that there are many underlying resource use and socio-cultural issues that may be challenges or opportunities in further development of the concept; and that it is the role of the biosphere reserve as a mechanism for enhancing local, regional, and multi-jurisdictional cooperation that is most needed in the area. Issues raised during the study may be relevant to the development of the biosphere reserve concept in the Bay of Fundy or elsewhere in the Atlantic region. This paper represents an attempt to draw out generic lessons learned that may serve as feasibility criteria for the development of coastal biosphere reserves.

Introduction

If the declining health of the world's coasts and oceans is any indicator, identifying appropriate mechanisms for the long-term protection of coastal environments has proven to be a difficult task the world over. This is certainly true in Atlantic Canada, where, despite a historical reliance on coastal and marine resources, conservation efforts have been largely concentrated in terrestrial areas. The conflicting needs of a wide variety of resource users, governments, and non-governmental organizations have made viable coastal conservation a serious challenge in the region.

Based on the notion of incorporating human activities and livelihoods into long term conservation; the United Nations Educational, Scientific and Cultural Organization (UNESCO) biosphere reserve model has been attracting growing interest in communities across Canada. Several proposals for Atlantic Canadian biosphere reserves have emerged in recent years, including those for coastal biosphere reserves in southwestern Nova Scotia (Miller *et al.* 1999), and the Bay of Fundy (Resource Management Associates 2000).

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[1] Many of the ideas contained in this paper were presented at the Fourth International Conference on Science and the Management of Protected Areas in a paper entitled "It could work: applying the UNESCO biosphere reserve concept in coastal Nova Scotia".

A preliminary assessment of the feasibility of developing a coastal biosphere reserve in southwestern Nova Scotia has been conducted (Ravindra 1998). Following a brief review of the biosphere reserve concept and its application to coastal areas, this paper presents some of the lessons learned that may be relevant to the development of other coastal biosphere reserves in the region.

What is a biosphere reserve?

The goal of the biosphere reserve programme is to reconcile the conservation of biological diversity with the preservation of economic and cultural values, in order to satisfy human needs without compromising the health and integrity of the natural systems upon which life depends (Batisse 1997, Batisse 1990). Biosphere reserves are thus areas of land or sea that are given international recognition for promoting and demonstrating a balanced relationship between humans and the biosphere (UNESCO 1996). As such, they are intended to be *models* of sustainability that can influence their surrounding regions.

In order to achieve this lofty goal, biosphere reserves have three complementary functions: the *conservation* of ecosystems, habitats, landscapes, species and genetic diversity; socio-culturally and ecologically sustainable *development*; and the building of local capacity for conservation and development by providing *logistic support* for research and monitoring, education and training, and the exchange of information with regional and international partners (UNESCO 1996).

On the ground, biosphere reserves typically include legally protected *core areas* (such as National Parks or Wildlife Areas) that protect areas of high diversity, endemic species, or special habitat features (*e.g.* estuarine areas, spawning grounds, or unique geological features). Biosphere reserves also include *buffer areas* that protect the core, as well as a vast, often dynamic *area of cooperation* where sustainable resource use practices can be developed and demonstrated. This area of cooperation provides the opportunity for local landowners, municipalities and communities to 'opt in' to the biosphere reserve.

Potential benefits in coastal areas

Cooperation and coordination

Individual biosphere reserves are established and managed through the participation of local stakeholders, and are administered through cooperative agreements between local communities, non-governmental organizations, universities, governments, industry, and other interested parties (Batisse 1986). By focussing on cooperation, the biosphere reserve can serve as a politically neutral framework for reconciling resource use and other conflicts; as well as for addressing issues of mutual concern; such as property rights or economic development (Francis 1993). This is particularly relevant in the coastal context, and increasing user conflicts in an area lacking effective cooperative management might be a suitable reason for establishing a coastal biosphere reserve.

The biosphere reserve can furthermore play a coordinative role, helping to overcome the sectoral differences that often frustrate successful management in coastal areas (Clark 1991). For example, development of a biosphere reserve could forge links between existing protected areas and individuals and organizations interested in sustainable resource use and monitoring activities.

Another good reason for the establishment of a biosphere reserve might therefore be that a regional coordinating entity is needed in the coastal area (Ravindra 1998).

Local context for scientific research

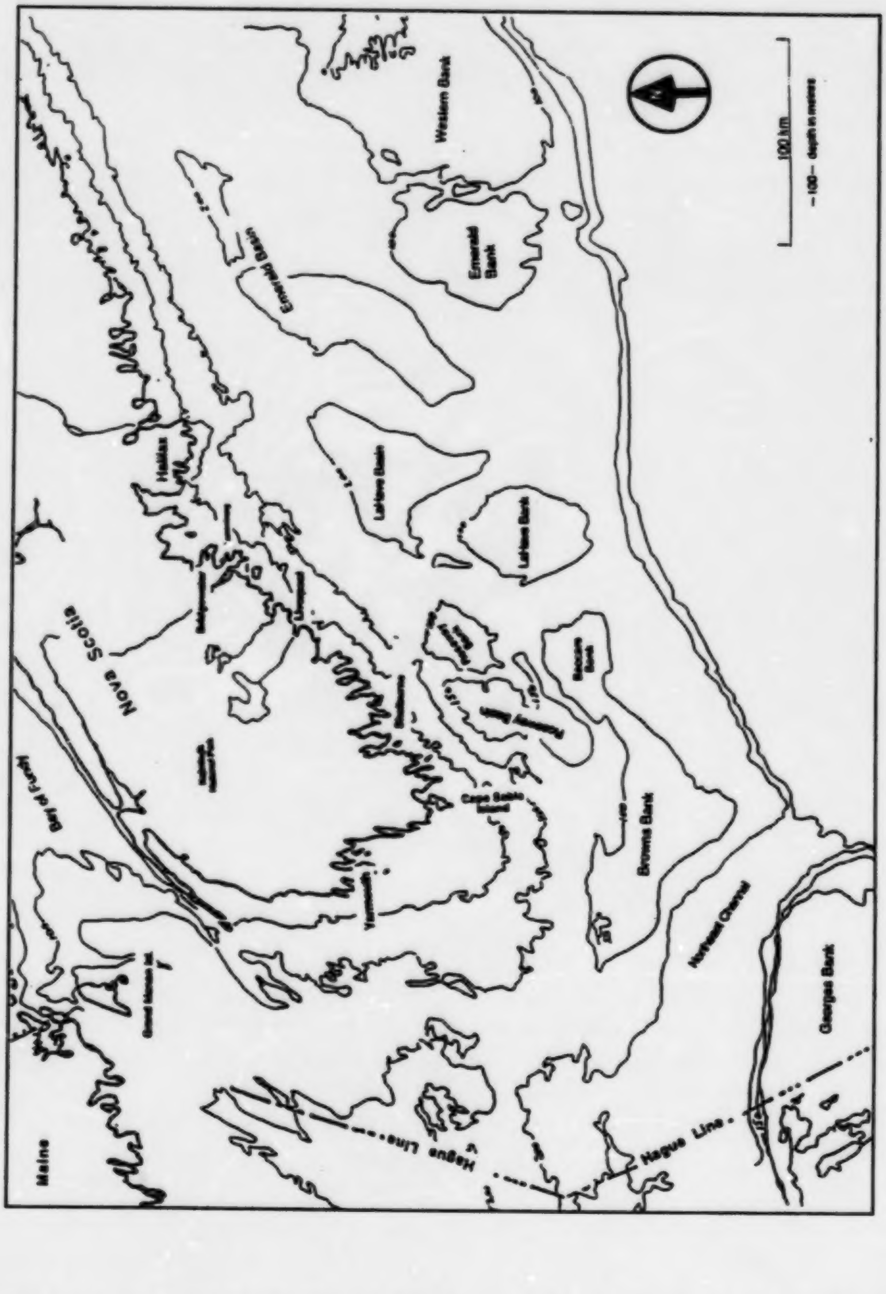
The cooperative framework of the biosphere reserve model can facilitate integrated and multidisciplinary research towards sustainable resource use. The biosphere reserve programme can help to create a feedback loop between science and management such that monitoring and evaluation activities occurring within biosphere reserves can play a role in determining ecologically acceptable levels of resource use in coastal areas. Furthermore, the biosphere reserve provides a framework within which fishermen, tourism operators, industry and other users of the coastal zone can be involved in research – both in helping to set the research agenda so that it responds to local needs; and in the collection of information. This is especially useful in the marine environment, where research and monitoring activities are much more costly than on land.

Everyone's knowledge is valuable

An interesting element of the biosphere reserve approach to knowledge is that it recognizes the role of values in scientific research (Engel 1989) and emphasizes the incorporation of traditional ecological knowledge in decision-making (UNESCO 1996). This is particularly important in the marine environment where fishermen and other coastal users have a wealth of long-term knowledge about the characteristics and dynamics of the ocean and marine species.

Scotian Coastal Plain Initiative

Over the past fifteen years, at least three different proposals for a biosphere reserve based on southwestern Nova Scotia have been put forward (Agardy and Broadus 1989, Francis and Muncro 1994, Miller *et al.* 1999). One of these proposals integrates the terrestrial and marine environments, proposing a 'Scotian Coastal Plain' biosphere reserve that would extend from Kejimkujik National Park to the edge of the continental shelf, including the coastal communities between Bridgewater and Yarmouth, as well their corresponding marine areas in a vast area of cooperation (Miller *et al.* 1999). The general area is shown in Figure 1. A preliminary feasibility assessment evaluated whether the Scotian Coastal Plain study area meets biosphere reserve criteria; and sought feedback about the idea from four key partner groups -- fisheries, tourism, environment, and municipal government (Ravindra 1998).


Maine
Bay of Fundy
Nova Scotia
Grand Manan Isl.
Yarmouth
Cape Sable Island
Halifax
Western Bank
Emerald Bank
Emerald Basin
LaHave Basin
LaHave Bank
Baccaro Bank
Browns Bank
Northeast Channel
Georges Bank
Hague Line
Hague Line
100 km
-100- depth in metres

Source: M. Ravindra. 1998. Applying the UNESCO biosphere reserve concept in coastal Nova Scotia: a preliminary feasibility assessment. MES Major Paper, York University.

Figure 1. General Scotian Coastal Plain area, showing major banks and basins.

Generally speaking, the Scotian Coastal Plain area meets the international and national biosphere reserve criteria. There is a wide diversity of landscapes, ecosystems, and habitats, in both terrestrial and marine environments. A relatively high proportion of the land is already legally protected and both near and off shore marine conservation initiatives are under development. The area is strongly resource-dependent, with a long-standing reliance on marine resources. With the decline of the fishery, there is growing interest in cooperative management and sustainable use of the ocean's resources; and there is a wide variety of conservation and resource management related research and monitoring occurring in the coastal and marine environments (Ravindra 1998).

Discussion with representatives of potential partner groups revealed a high level of interest in the biosphere reserve idea, especially from the tourism, municipal government, and environmental sectors. These groups were particularly attracted to two aspects of the biosphere reserve – its potential to help coordinate disparate conservation and sustainable development activities occurring in the area; and the prospect of international designation raising the profile of the area. Representatives of the fishery were less unanimous, focussing more on the high level of conflict within the industry; and the need for an alternative approach to fisheries management (Ravindra 1998, Ravindra 2000).

The underlying issues that emerged during the feasibility study are summarized in Table 1. The resource use concerns raised reflect a concern for the way the land and the sea are *used*; and the social and cultural factors form the *context* within which these resource use and other issues exist. Both are important to further planning and management of a biosphere reserve in southwestern Nova Scotia and are liable to surface wherever coastal biosphere reserves are discussed in the Atlantic region.

Focus on Fundy?

Relative to the conflictual nature of fisheries issues in southwestern Nova Scotia, the Bay of Fundy looks like a model of cooperation and community management. As several respondents pointed out, there is a process of capacity building underway among coastal communities, environmental groups, fishermen's groups, and scientists. Organizations like the Bay of Fundy Ecosystem Partnership and the Bay of Fundy Fisheries Council have objectives similar to the biosphere reserve programme and could provide the local institutional frameworks necessary to further develop the idea in the area. The Bay of Fundy may well be an easier place in which to pioneer the coastal biosphere reserve concept in Atlantic Canada, and a proposal for just such an initiative is currently in its initial stages (Resource Management Associates 2000)[2].

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[2] It is not inevitable that development of a Bay of Fundy biosphere reserve be incompatible with one on the Scotian Coastal Plain. Marine linkages between the Western Scotian shelf and the Bay of Fundy may in fact make this a more natural focus for a model coastal biosphere reserve.

Table 1: A sample of challenges and opportunities for biosphere reserve development in the Scotian Coastal Plain study area (Ravindra 2000).

Resource use issues	
Challenges	**Opportunities**
Lack of cooperation amongst sectors of the fishery - gear conflict - quota conflict Fear of loss of sovereignty - concern that tourism and recreational activities displace fishing activities - fear of loss of access to coastal resource (especially fishery) - concentration of power in big companies No consensus on what constitutes 'sustainable management'	Widespread interest in sustainable fisheries - support of marine conservation and the concept of closed areas - interest in research and monitoring for fisheries management (especially involving fishermen in data collection) - tourism industry interest in and support for protecting inshore fishery Perception of loss of community sustainability and interest in restoring it - preserve small scale resource uses and industries
Socio-cultural issues	
Challenges	**Opportunities**
Deep mistrust of government - anger and resentment towards DFO - suspicious of Parks Canada's agenda Sense of powerlessness Fear of change, outsiders Confusion about BR concept - language is problematic, *e.g.* 'core', 'reserve' - large educational process needed to clarify Different value systems among user groups/stakeholders	Willingness/wish to participate - interest in community meetings/brochure to put BR idea to wider audience - interest in a BR related information or education program Love of area - strong feelings of pride in the area - sense of solidarity - passion for the coastal landscape - willingness to work extremely hard

Other concerns raised

Ecological and economic impacts of:
- new species fisheries (fishing lower on the food chain)
- development of aquaculture
- mining, uranium claims
- development of offshore oil and gas

Loss of coastal access
- wharves
- publicly owned coastal lands

Increasing sea traffic, high speed ferries & potential conflict with wildlife species and conservation areas

Forestry practices; Aboriginal forestry

Environmental problems: *e.g.* habitat loss, acidification

Feasibility criteria

Behind the national and international criteria for the establishment of biosphere reserves is another layer of 'hidden criteria' – characteristics of biosphere reserves and other coastal conservation initiatives that *work* (Ravindra 1998). While not necessarily officially required, these can be thought of as 'feasibility criteria' – actions or approaches which may enhance the feasibility of actually developing a successful biosphere reserve. Given the local concerns and issues summarized in Table 1, and the attendant challenges to coastal biosphere reserve establishment in southwestern Nova Scotia; a set of 'feasibility criteria' are proposed in Table 2. The immense flexibility of the biosphere reserve concept means that there is no single 'recipe' for success, however these suggestions are offered as a means of improving the feasibility of developing a coastal biosphere reserve in southwestern Nova Scotia, the Bay of Fundy, or elsewhere in the Atlantic region.

Conclusions

The establishment of biosphere reserves is usually driven by either the recognition of conservation, research and sustainable management practices; *or* by the presence of resource conflicts and the need for just such a cooperative mechanism to resolve them (UNESCO 1996, Ramsay and Sian 2000). As such, the *process* of moving towards a biosphere reserve (and the multi-stakeholder discussions and regional cooperation this engenders) may be as much a benefit as the actual designation of the biosphere reserve itself. The issues and suggestions raised in this paper are meant to draw attention to some of the bumps that may be encountered along the way; and to provide the beginnings of a road map which may help to steer the process. The rest will be discovered en route -- what better time to start than now?

Table 2: Selected feasibility criteria for coastal biosphere reserves.

General

- Coastal biosphere reserves will need to include seemingly distant areas (*e.g.* inland watersheds, offshore upwelling areas, fishing territories) related to coastal health and sustainability.
- There may be the presence of conservation, resource use, or development issues that would benefit from more extensive cooperation among agencies and groups.

Conservation

- The proposed area will normally be known for its natural features and values.

Sustainable Development

- Should be able to serve as a pilot site for developing and promoting sustainable development on a regional scale (*e.g.* environmental design initiatives; cooperative projects, etc.).
- May have the capacity for low impact tourism or ecotourism activities.

Logistical Support/ Building Local Capacity

- Presence of institutional support for environmental education and training initiatives and opportunities.
- Mechanisms whereby resource users play a role in setting the research agenda so that research addresses local needs and concerns in addition to expanding scientific knowledge.
- Ways for local people to participate in research and monitoring efforts.
- There should be committed academic and non-governmental organizations that can provide technical assistance to government and community groups.
- There should be a means to communicate research to the local population through extension programmes, demonstration activities, cooperation with local schools and technical and academic institutions.
- There should be viable community organizations, including recognized citizen's groups who are empowered to initiate programmes and activities that complement those of government.

Local Organization & Leadership

- Form a biosphere reserve committee representative of a broad range of local interests and authorities. Its objective is to define and coordinate the biosphere reserve programme and to serve a preliminary coordinative function for activities taking place in the region.
- It is essential that key non-government people be involved in the committee, as well as individuals who have credibility in the fishing community.
- There is usually a local champion or several champions to move the biosphere reserve idea forward.
- Initial support from an agency, institution or individual may be required to facilitate development of coordinating committee.

Communication

- Develop an information programme to communicate the biosphere reserve idea widely to the local community and other stakeholders, and to solicit participation in development of the biosphere reserve (this could include holding community meetings; producing a brochure).
- Ensure that language appropriate to the historical and cultural context of the region is used in all communications about the biosphere reserve concept (*e.g.* 'reserve' and 'core area' aren't well received in southwestern Nova Scotia. 'Initiative', 'monitoring area' or 'control area' are some alternatives).
- Make it clear who stands to benefit from the biosphere reserve. Local support may be eroded if the primary beneficiaries are foreign visitors, urban people, or scientists.

Participation

- Ensure local stakeholders and communities are involved in the development of the biosphere reserve concept. The geographical area, the structure, and the management regime of the biosphere reserve should be reflective of the needs of the people who rely on it, for economic, cultural, or personal reasons.
- Ensure that there is a participatory process that allows ongoing resolution of conflicts and development of consensus among partners.
- Allow enough time for extensive participation (don't rush!).

Management

- Draw up a set of principles according to which the biosphere reserve could be further developed, implemented and managed (*e.g.* ecological integrity, adaptive management, sustainable development, precautionary principle).
- Maintain a non-partisan perspective -- conflicts among different sectors could sabotage the biosphere reserve process if they are allowed to become a driving force. Focus on finding collective solutions and rational discussion of resource use conflicts rather than use of the biosphere reserve concept as a way of lobbying against specific initiatives.
- Develop and emphasize the coordinative function of the biosphere reserve concept by linking up with ongoing coastal zone management and sustainable development activities in the region. Regional conservation, development, and research and education interests can be brought together under the aegis of biosphere reserve designation.
- Undertake a visible project that brings together partners and beneficiaries of a coastal biosphere reserve, and that demonstrates the benefits of a biosphere reserve in the area (*e.g.* eco-labelling of sustainably harvested biosphere reserve fishery and other food products; community waste or energy auditing).

(Derived from Agardy 1990, Birtch and Lieff 1993, Birtch *et al.* 1993, UNESCO 1996, Ravindra 1998, Helmer 2000, Ravindra 2000)

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POSTER PRESENTATIONS

MONITORING SEAWEED DIVERSITY IN THE BAY OF FUNDY, NEW BRUNSWICK, CANADA

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Abstract

Detailed records of seaweed diversity in southern New Brunswick were produced on and off up until the late 1970's. Since then, formal seaweed diversity monitoring has ceased, presumably due to a lack of monetary and human resources. The objective of this project is to conduct a long-term floristic monitoring program for red, green and brown algae in the Bay of Fundy. Specifically, we are sampling intertidal macroalgal assemblages to 1) obtain current and detailed baseline records, 2) compare contemporary and historical data to highlight changes in the flora, 3) gain insight into the range of variation in Fundy seaweed communities, 4) compare methods of sampling and analyzing intertidal seaweed community data, and 5) pinpoint sites of high diversity for conservation purposes. Our results to date indicate that certain sites within the Bay of Fundy show symptoms consistent with reported indicators of anthropogenic pressure. At these sites, we observed a lower percent cover and diversity of red algae, blooms of ectocarpoid brown algae, and a higher percent cover of mussels, when compared to other sites. Symptoms that were not observed include reduced Shannon diversity index (H') and extensive blooms of green algae.

Key words: Bay of Fundy, biodiversity, biomonitoring, macroalgae, seaweed.

Introduction

Historical records of the seaweed diversity along the southeastern New Brunswick coast are available from the late 1800's to the late 1970's. For the period between 1980 and the present, comprehensive data sets are scarce, if extant at all. Floristic checklists have been published for eastern Canada (*e.g.* South 1984), but nothing focusing specifically on the Bay of Fundy, or documenting abundance of non-commercially harvested seaweeds.

Over the past 20 years, the array of anthropogenic pressures on the Bay of Fundy has continued to diversify and intensify. Examples include increased habitat disturbance, eutrophication, addition of chemical contaminants, and an increase in both the amount and variety of biological resources harvested (Percy and Wells 1996). In particular, salmon aquaculture has become a dominant industry in southwestern New Brunswick. Critics of this industry cite it as a major contributor to increased nutrient loading in coastal waters (Gulf of Maine Working Group 1990), chemical contamination from compounds of the cage building materials (Zitko 1984) and introduced chemicals used in the control of pests (Collier 1998).

The effects that these increased pressures are having on Fundy seaweed communities have not been formally quantified. However, there is substantial literature describing anthropogenically induced changes to benthic macrovegetation in other parts of the world, with particular attention given to the effects of increased nutrient levels. Schramm and Nienhuis (1996) discuss the following generalized effects of increased anthropogenic pressure on Western European seaweeds and coastal biotic communities:

- Reduction in lower intertidal and subtidal red algae, and decline or disappearance of certain perennial algal communities.
- Blooms of short lived filamentous algae, such as *Ectocarpus* spp. and *Pilayella littoralis* (Linnaeus) Kjellman.
- Increased number and density of benthic filter feeders (*e.g.* mussels) and detritus feeders (*e.g.* sea urchins).
- Green tides (extensive blooms of *Enteromorpha* spp., *Ulva* spp. and *Cladophora* spp.).
- General impoverishment of the flora, and reduction in species numbers and diversity.

In order to determine if similar changes are occurring within the Bay of Fundy, we have implemented a long-term seaweed monitoring program. Additionally, this monitoring will allow us to 1) obtain current and detailed baseline records, 2) compare contemporary and historical data to highlight changes in the flora, 3) gain insight into the range of variation in Fundy seaweed communities, and 4) pinpoint sites of high diversity for conservation purposes.

This report focuses on the first objective: to determine if some sites within the lower Bay of Fundy exhibit any of the above listed 'impact' characteristics. Our methodology, preliminary results and interpretations are described here.

Methods

Six intertidal sites around the southeastern New Brunswick coast of the Bay of Fundy were selected, based on availability of historical records, perceived level of human impact and degree of wave exposure. The selected sites are: Grand Manan (exposed and sheltered), Letite (exposed and sheltered) and Lepreau (exposed and sheltered). The site locations are indicated in Fig. 1. At each location, a site is defined as a selected 30 m wide band running from high water to mean low water.

Sites are being sampled three times a year for species abundance, species presence/absence and abiotic parameters. Species abundance is sampled using four random transects with each transect stratified into upper, mid and lower intertidal zones. Six 50 cm x 50 cm random-point-encounter quadrats (Jones *et al.* 1980) are being sampled along each transect (2 per zone). All seaweeds within the quadrats are identified to species, and a percent cover value is assigned to each. Species lists are compiled using quadrat data and augmented with haphazard site searches. Abiotic parameters being sampled include temperature, salinity, and nitrogen & phosphorus levels (using algal tissue and seawater analysis).

Comparisons are only considered within equivalent wave regimes (*i.e.* sheltered or exposed sites). Specifically, sites are compared for differences in percent cover of red algae, number of red algal species, cover of opportunistic filamentous brown algae, cover of filter feeders (mussels), and cover of green tide species (*Enteromorpha* spp., *Ulva* spp., and *Cladophora* spp.). Differences in overall algal diversity were also monitored using the Shannon diversity index (H') (see Magurran (1988) for a discussion of diversity indices).

Statistical analyses are being applied to the percent cover values and the Shannon diversity index using two (or three) factor ANOVAs, using site, zone (and date) as fixed factors. In cases where heterogeneous variances were observed, data were transformed using the square root or Log_{10} (datum + 0.01) (Underwood 1997). *Post hoc* pairwise comparisons were done using Tukey's test. Number of species was not analyzed statistically, as only two lists per site have been compiled.

Results

To date, two sampling episodes have been completed: May and August, 2000. We have drawn comparisons between the sites for signs of impact, and these comparisons reveal significant differences between sites, as outlined below.

A significantly lower percent cover of intertidal red algae was seen at both the Letite exposed and sheltered sites ($F_{5,23} = 20.257$, $p < 0.001$), compared to the Grand Manan and Lepreau sites (Fig. 2). The number of intertidal red algal species found at Letite was also lower (Fig. 3). Species count and cover of green and brown algae are included for completeness (Figs. 2, 3). The percent cover of *Ectocarpus* spp. and *Pilayella littoralis* (Fig. 4) was significantly higher in the spring, at both the Letite exposed and sheltered sites, compared to Grand Manan or Lepreau sites ($F_{5,23} = 11.529$, $p < 0.001$). The average spring percent cover at the Letite sites was 7 % (exposed) and 15 % (sheltered), compared to a range of less than 0.5 % to 2 % at all other sites. The August sampling did not show a difference in filamentous brown algae between sites, and average percent cover values ranged from 0 % to 2 %. The percent cover of mussels (Fig. 5) in the lower intertidal was minimal or absent at Grand Manan and Lepreau sites, but was significantly higher at Letite exposed and sheltered sites ($F_{5,23} = 5.989$, $p < 0.05$) with an average of 6 %. Observations during sampling indicate that this is likely an underestimate of the actual percent cover of mussels, because our sampling method targets the algal canopy, not the substrate. The percent cover of green tide species (Fig. 6) was variable both between sites and within sites over time, but nothing approaching a bloom or green macroalgal mat was observed. In the May sampling episode, Grand Manan sheltered showed the highest at an average of 11 % cover, and Lepreau sheltered was significantly lower with the average around 1 % cover ($p < 0.05$). No difference was seen between the exposed sites. In the August sampling episode, the Grand Manan and Lepreau exposed sites were higher than the Letite exposed site, and there was no difference observed between the sheltered sites.

Shannon diversity index (H') (Fig. 7) was not significantly different at any of the exposed sites. Lepreau sheltered exhibited a lower Shannon diversity index than Letite and Grand Manan sheltered sites ($p < 0.05$).

Temperature and salinity were not significantly different at any of the sites, and results of nutrient analysis are not currently available.

Discussion

Seaweed communities in Western European countries have been documented to show changes when subjected to increased nutrient loads (Schramm and Nienhuis 1996). Within the Bay of Fundy, we have found that the Letite exposed and sheltered sites exhibit some, but not all of the characteristics associated with "impacted" sites in Western Europe, while the Grand Manan and Lepreau sites do not. Specifically, Letite exposed and sheltered sites show a lower percent cover and species diversity of red algae, blooms of short-lived filamentous brown algae (*Ectocarpus* spp. and *Pilayella littoralis*) and a significantly higher cover of mussels. Reported indicators of impact that were not observed here include green tide events and a general impoverishment/decrease in diversity of the flora, as indicated by the Shannon diversity index (H').

The lower percent cover and species richness of red algae at the Letite sites is most noticeable in the lower intertidal zone. Species that are expected at Letite exposed, but were absent include: *Callophyllis cristata* (C Agardh) Kützing, *Membranoptera alata* (Hudson) Stackhouse, *Phycodrys rubens* Batters, and *Ptilota serrata* Kützing. The causes of this decrease are unknown at this time, but other studies have linked decreased red algal diversity to competition with macroalgal blooms and mussels for substrate, altered light levels due to reduced penetration through the water column, and scouring/siltation effects (Fletcher 1996, Johansson *et al.* 1998).

Blooms of filamentous *Pilayella littoralis* and *Ectocarpus* spp. are considered to be indicators of eutrophic waters (Fletcher 1996). The increase in percent cover of ectocarpoids would suggest that elevated nutrient levels are present at the Letite sites. Extensive and continued ectocarpoid blooms are reported to have detrimental effects on the fucoid (*Fucus* spp., *Ascophyllum nodosum* (Linnaeus) Le Jolis) algae they epiphytize owing to increased drag, nutrient competition, and blockage of light for photosynthesis (Vogt and Schramm 1991, Chopin *et al.* 1996). We did not observe a lower cover of fucoids at any of the sites to date but our future efforts will continue to monitor for this aspect of floristic change.

The direct ecological interactions of mussels with algae make these organisms of interest here. Mussels compete for space with algae, yet do not provide a suitable alternate substrate for many species (Fletcher 1996). As well, increased filter feeding by mussels can remove algal spores before they settle (Fletcher 1996), which can affect recruitment potential. It is thought that an increase in organic materials will provide a constant source of food, allowing mussel populations to flourish. The Letite exposed site had substantial levels of mussels compared to the other sites (Fig. 5) and anecdotal evidence suggests that much of the shift from algal to mussel dominated substrate at the Letite sites has occurred over the past five to ten years (Chopin and Saunders, pers. observations).

The average percent cover of green algae seen in this study is below 10 %. Reports of green tide blooms in Western Europe describe extensive green macroalgal mats (Fletcher 1996), much higher than what we documented here. This lack of green tide mats, particularly at the putatively eutrophic Letite sites, could be due to the consistently lower water temperature in the Bay of Fundy, alternate substrate requirements (*e.g.* mud flats), or germination and herbivore grazing related factors, as reported by Lotze *et al.* (1999). Green tide mats have however, been observed in the region at sites other than the six selected for our study (Chopin, pers. observations).

The Shannon diversity index did not resolve lower diversity at the Letite sites as might be anticipated based on the previous observations. This may be due to the fact that most of the differences were qualitative (species assemblages) as opposed to quantitative (relative species counts and abundance). The Shannon diversity index does not reflect differences in community composition, only species number and relative cover. We are exploring other analysis methods and indices that reflect taxonomic relationships between species, and these may offer a better resolution (Clarke 1993, Warwick and Clarke 1998).

Conclusions

The Letite exposed and sheltered sites are showing symptoms consistent with reported indicators of anthropogenic pressure, whereas the Grand Manan and Lepreau sites are not. It is not possible to determine the nature of the specific pressures within the scope of this study. Nonetheless, it is noteworthy that aquaculture operations are located within 200 meters of the Letite sheltered site, and 500 meters of the Letite exposed site, and may be elevating nutrient and siltation levels (Gulf of Maine Working Group 1990). This will form the basis of our continued emphases as abiotic data are incorporated into our analyses and conclusions.

Acknowledgements

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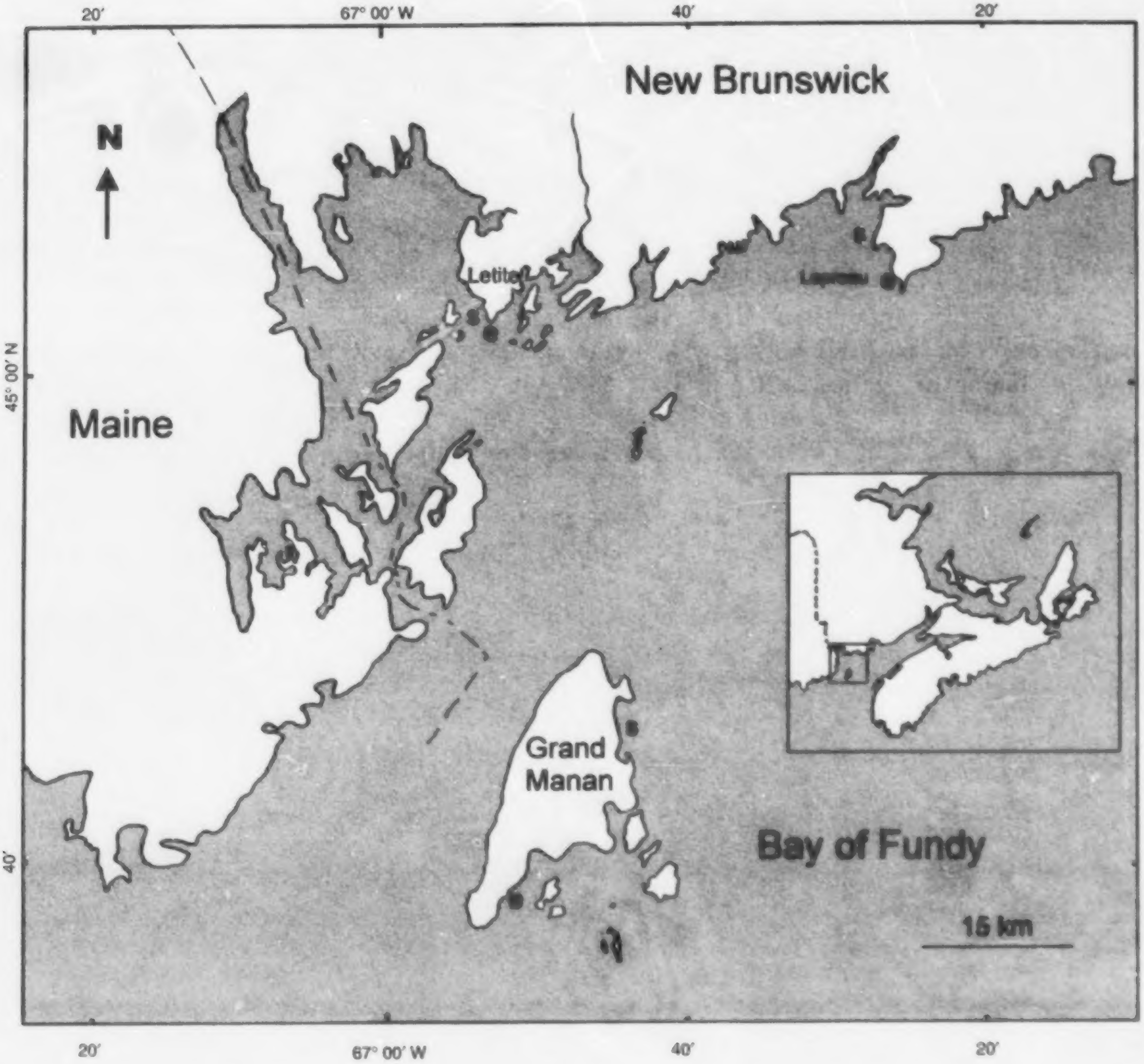
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Figure 1. Map of monitoring sites at Letite, Lepreau, and Grand Manan Island, New Brunswick. (s = sheltered, e = exposed). Inset is of the Canadian Maritime Provinces.

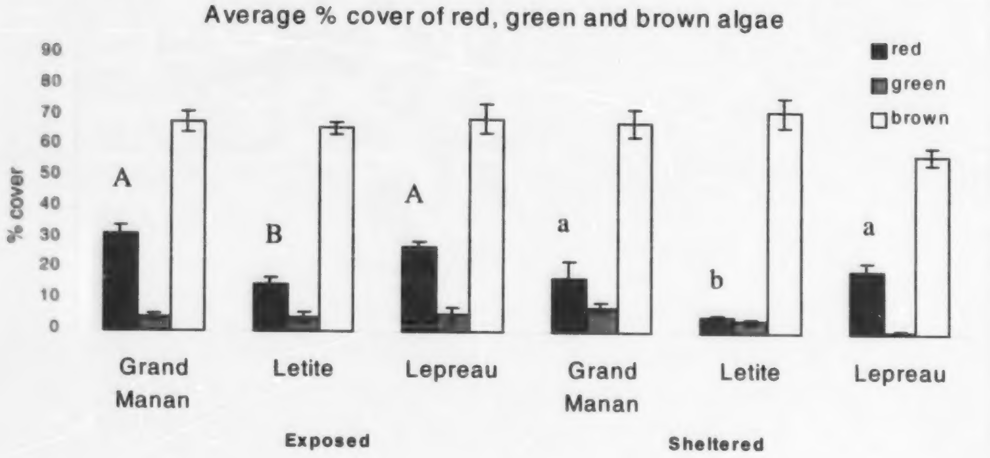

Figure 2. Average percent cover of red, green and brown algae, May and August 2000 combined. Comparisons are drawn only within wave exposure regimes (exposed and sheltered). Bars with the same letter are not significantly different ($p < 0.05$). Uppercase: exposed sites; lowercase: sheltered sites. +/- SE, n = 8.

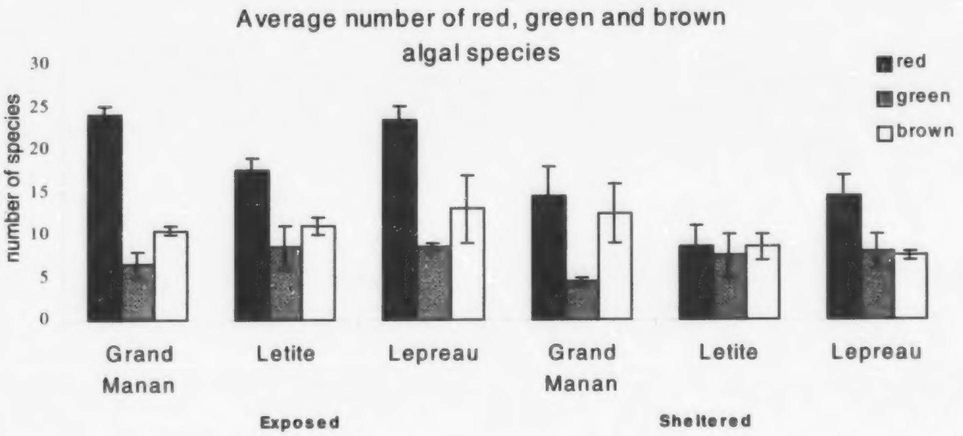

Figure 3. Average species richness of red, green and brown algae, May and August 2000 combined. Comparisons are drawn only within wave exposure regimes (exposed and sheltered). +/- SE, n = 2.

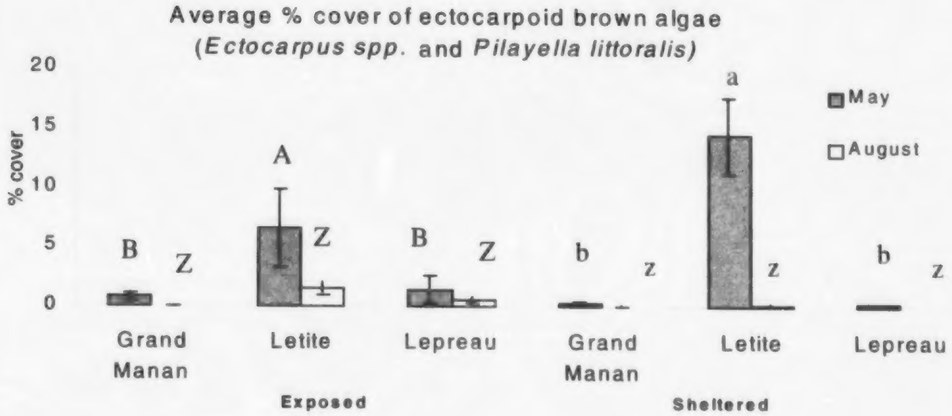

Figure 4. Average percent cover of ectocarpoid brown algae, May and August 2000. Comparisons are drawn only within wave exposure regimes (exposed and sheltered), and within date. Bars with the same letter are not significantly different ($p < 0.05$). Uppercase: exposed sites; lowercase: sheltered sites. +/- SE, n = 4.

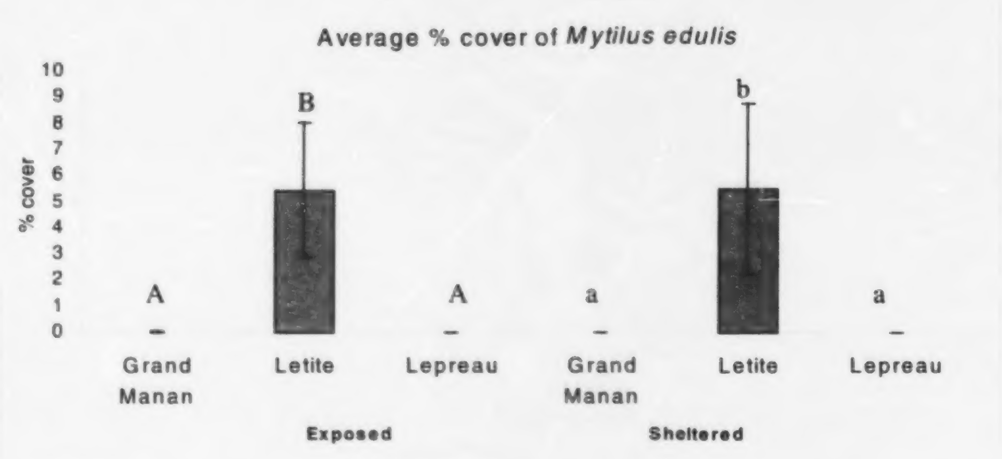

Figure 5. Average percent cover of *Mytilus edulis*, May and August 2000 combined. Comparisons are drawn only within wave exposure regimes (exposed and sheltered). Bars with the same letter are not significantly different ($p < 0.05$). Uppercase: exposed sites; lowercase: sheltered sites. +/- SE, n = 8.

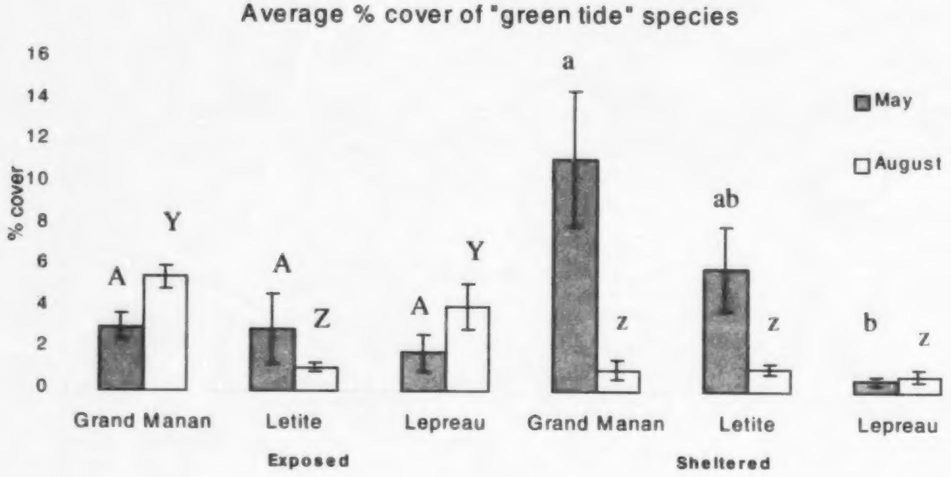

Figure 6. Average percent cover of "green tide" species (*Cladophora* spp., *Ulva lactuca* and *Enteromorpha* spp.), May and August 2000. Comparisons are drawn only within wave exposure regimes (exposed and sheltered), and within date. Bars with the same letter are not significantly different ($p < 0.05$). Uppercase: exposed sites; lowercase: sheltered sites. +/- SE, n = 4.

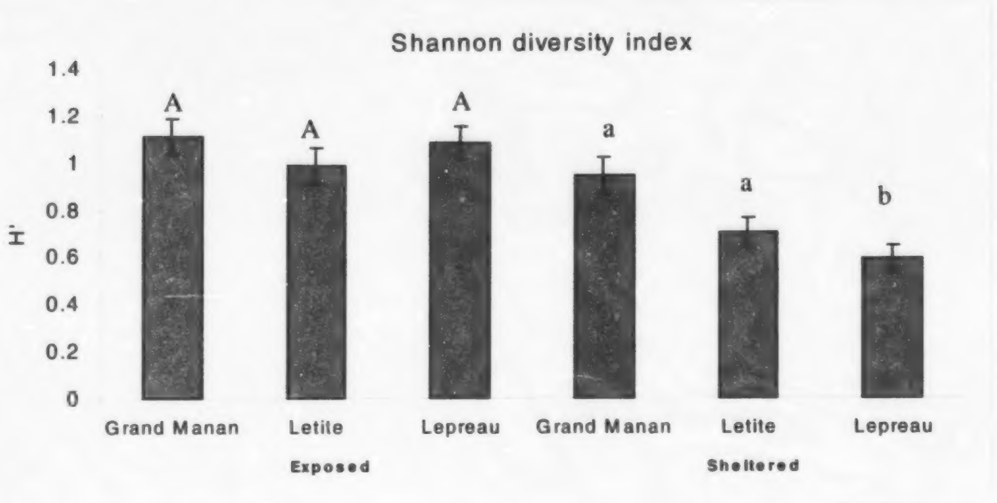

Figure 7. Average Shannon diversity index (H'), May and August 2000 combined. Comparisons are drawn only within wave exposure regimes (exposed and sheltered). Bars with the same letter are not significantly different ($p < 0.05$). Uppercase: exposed sites; lowercase: sheltered sites. +/- SE, n = 8.

OCEANOGRAPHY AND OTHER STUDIES IN MUSQUASH - A PROPOSED MARINE PROTECTED AREA

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The Musquash Estuary is located approximately 20 kilometers west of the city of Saint John, New Brunswick. The estuary and salt marsh complex is critical to the health of the marine ecosystem, being a highly productive area, and supporting a variety of species. Studies have identified the Musquash estuary as a significant area and it is presently being reviewed by DFO as a potential Marine Protected Area.

Together with the Musquash Marine Protected Areas Planning Group, DFO will conduct studies on this coastal ecosystem to help understand the function and role of the estuary in the Bay of Fundy ecosystem. As well, DFO will contribute to the group's assessment of activities and their impacts in and around the estuary. As the next step a management plan will be developed to identify the specific actions required to provide long-term protection for the area. Studies have been initiated in order to obtain basic descriptive oceanography for Musquash Harbour in support of the MPA proposal. This baseline information will provide a start in terms of understanding and interpreting the bio-physical system. Initially this information will yield a qualitative description of the oceanography of Musquash Harbour; more detailed analysis coupled with some modeling might then be undertaken in order to address scientific and management questions.

This poster presentation highlights the proposed scientific studies for the area, and provides a summary of preliminary oceanographic observations, as well as the test sampling of plankton and sublittoral benthic communities, accomplished in the summer of 1999. Existing literature is reviewed, long-term GIS referenced sampling plans are described, and other scientific studies are suggested.

FUNDAMENTALS OF FUNDY TIDES

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Abstract

Local tidal characteristics along the eastern Canadian seaboard result from a combination of diurnal (daily) and semi-diurnal (twice daily) tides. At most locations, as in the Bay of Fundy, the semi-diurnal tide is dominant.

Differences in tidal range through the Gulf of Maine - Bay of Fundy system are governed by the rocking motion of a tremendous seiche, whose period of oscillation coincides with the ocean's tidal movement. Marigrams of Bay of Fundy tides exhibit essentially sinusoidal curves. High tides are developed over a long distance in response to the Moon's and Sun's gravitation on the water particles forming the oceans. Although dominantly semi-diurnal, Fundy tides do experience marked diurnal inequalities. Thus the overlapping of the cycles of spring and perigean tides every 206 days results in an annual progression of 1.5 months in the periods of extra high tides. Depending on the year, these strong tides can therefore occur at all seasons in the Bay of Fundy. So in addition to the annual progression of 1.5 months in the highest tides, the dominance of semi-diurnal tides in the Bay of Fundy results in considerable variation throughout the year. Distinct cycles of 12.4 hrs, 24.8 hrs, 14.8 days, 206 days, 4.52 yrs and 18.03 years are recognized. Using Saint John as reference port, tidal movements at Herring Cove illustrate the annual expected variations.

"I know not what I may appear to the world, but to myself I seem to have been only like a boy playing on the sea shore, and diverting myself in now and then finding a smoother pebble or a prettier shell than ordinary, whilst the great ocean of truth lay all undiscovered before me."

Isaac Newton (1642-1727)

Introduction

Tides, the longest of oceanic waves, are the alternate rising and falling of sea level due to the gravitational effects exerted on the Earth by the Moon and Sun. Since time immemorial people have recognized that there is some connection between the tides and the positions of the Moon and Sun relative to Earth. However the relative motions of these celestial bodies are by no means obvious, and their influence on tidal events results in complex flow patterns. Nevertheless, the magnitude of the effects which generate tides can be rather precisely calculated, the chief caveat being that the ocean's response to these effects will be constrained by continental land masses, the Earth's rotation, the geometry of ocean basins and the transience of weather. According to Newton's equilibrium tidal theory, an ideal wave forms instantaneously upon an earth uniformly covered by a deep layer of water, under the influence of the Moon's and Sun's gravitational effects. It is important to realize that this theory is not meant to provide a realistic picture of what actually occurs in nature. However, it does give very accurately the tidal periods, the relative forcing magnitudes and the astronomical phases of the tides, knowing just the astronomy. It is the cornerstone upon which tidal analysis and predictions are based.

Tidal predictions are based on harmonic analysis of local tides. In the Bay of Fundy (Fig. 1) the principal hydrographic station is located at Saint John, New Brunswick. Predictions are made and published annually for this reference port. Upon analysis the observed tides are broken down into a large number of cosine curves, so-called tidal constituents, each representing the influence of a particular tidal influence or characteristic of the local tide (Table 1). Thus the M_2 constituent represents the influence that the Moon has on the local tides, supposing for simplicity that it made a circular orbit around the Earth in the plane of its equator at a distance that would result in (most cases) average tides. The S_2 constituent represents the Sun's gravitational influence, assuming that Earth moves in a circular orbit around the Sun at a distance producing the average effect, and assuming the Earth's equator is located in the orbital plane, called the ecliptic. Other constituents make corrections to these basic assumptions, because of variations in the actual and sometimes apparent movements of these heavenly bodies. Constituents with the subscript "2" repeat themselves twice a day, causing two daily (semi-diurnal) tides. Those with subscript "1" occur once a day, and those with subscript "4", four times a day. The last applies to locations where shallow waters influence tides in such a way that their symmetry is lost, causing the water to rise faster than it will drop in the following ebb (Forester 1983, CHS 1981, 1994).

Nowhere does the pulsating ebb and flow of the tide beat more impressively than in the Bay of Fundy (Defant 1958). Here the tidal range pushes the 16 metre mark at times of particular astronomical conditions with or without extreme atmospheric disturbances. Fundy tides are an integral part of the semi-diurnal tidal system prevailing in the North Atlantic (Davis and Browne 1996).

Differences in the tidal range through the Gulf of Maine - Bay of Fundy system are governed by the rocking motion of a tremendous seiche, whose period of oscillation coincides with the ocean's tidal movement. The Bay of Fundy and its tidal processes together form a dynamic entity, impressive as a stand alone case of a macrotidal system. Here the tides rule over a host of physical processes, among them currents, bores, whirlpools, erosion, shifting sediments, estuarine evolution and the functioning of diverse ecosystems.

Origins

In Atlantic Canada there are usually two inequal tides a day. They are due to the combined gravitational effects of the Moon and Sun, and the centrifugal forces resulting from the revolution of the Earth-Moon and Earth-Sun systems around their common centres of gravity. For instance the Earth and the Moon revolve in essentially circular orbits round their combined centre of mass (barycentre) every 27.3 days (sidereal month). Thus each point on Earth has the same angular velocity of 2 pi per 27.3 days, and will experience an equal acceleration as a centrifugal force away from the Moon. The total of all these forces on the mass of the earth is balanced by the total gravitational effects of the Moon's mass on Earth's mass, keeping the Earth on its orbit, just as the gravitational effects of the Earth keep the Moon on its orbit (Doodson and Warburg 1941, OPEN 1993). The magnitude keeping these bodies on their respective orbits can be expressed with the following equation:

$$F_g = \frac{G \cdot M_e \cdot M_m}{R^2} \qquad \text{(equation 1)}$$

where M_e and M_m are the masses of the Earth and Moon, G the universal gravitational constant and R the distance between the centres of M_e and M_m. Further, the Moon's gravitational attraction on all particles making up the Earth are directed towards the centre of the Moon, and hence except for the line joining the centres of the Earth's and Moon's masses, will not exactly be parallel to the direction of the centrifugal force. The composite magnitude of the centrifugal and gravitational effects, known as the tide-producing force or effect (TPF) will depend on the distance of each Earth's particle from the centre of the Moon. This distance can be more or less than the value of R.

For instance the magnitude of TPF (Fig. 2) on a particle with the mass m at point Q, in relation to a similar particle at the centre of the Earth for example (given the Earth's radius = a), is:

$$TPF = \frac{G \cdot M_m \cdot m}{(R-a)^2} - \frac{G \cdot M_m \cdot m}{R^2} \qquad \text{(equation 2)}$$

In this equation the last part represents the equivalent centrifugal effect. The equation can be simplified by means of a calculus derivative to:

$$TPF = \frac{2 \cdot G \cdot M_m \cdot m \cdot a}{R^3} \qquad \text{(equation 3)}$$

At point Q (Fig. 2) the TPF acts toward the moon (a is positive), but at point P, away from it (a is negative). At these points the effect is perpendicular to the Earth's surface and, although at its maximum value, in relation to the Earth's gravity, it is insignificant and has negligible effect on raising the water surface. In the plane through the centre of the Earth and perpendicular to the line connecting it with the centre of the Moon, the TPF will be pointed toward the centre of the Earth. However, at points on the Earth's surface halfway between this plane and points an P (W, X, Y and Z), the horizontal components (tractive forces) of the TPF will be greatest, causing maximum effects and moving particles towards the points Q and P (Clancy 1969).

These forces will cause particles in the oceans to move along looping paths over limited distances. The rotation of the Earth will continuously change the TPF on each particle both in strength and direction. And since these particles are moving, the Coriolis effect will act upon every moving particle which is not located in the Earth's equatorial plane, thus changing the shape of these loops.

Because the Moon revolves about the barycentre every 27.3 days in the same direction as the Earth's rotation (24 hours), this rotation with respect to the Moon is 24 hours and 50 minutes (lunar day). Thus the times of high (or low) tides are nearly one hour later each following day. As discussed below, layers of complexity are added to the tides by the pattern of forces similar to that between the Moon and Earth set up by the Sun-Earth combination, the variable distance between Earth and the Moon because of the elliptical orbits, (contrast between perigee and apogee), the variable celestial position of Moon, Sun and Earth relative to each other (spring tides vs. neap tides) and the declinations of the Moon and Sun relative to the plane of the Earth's equator (causing diurnal inequalities).

Characteristics of Fundy tides

A branch of the Gulf of Maine, the Bay of Fundy evolved through a complicated process. A fault-bounded half-graben, the rift boundaries were established at the onset of the formation of the Atlantic Ocean, due to continental drift. Sedimentary infilling commenced 200 million years ago during the Triassic Period. During a late-drifting stage immediately following the Triassic Period, basaltic lava erupted upon older Triassic strata (Mossman and Grantham 1996). Subsequently the entire sequence was folded and uplifted. The disposition of basalt and the role of glaciation have been important controls on the geomorphology of the Bay, as on its tidal regime.

An average single tidal flow into the Bay matches the estimated total daily volume (ca. 104 km^3) of all the world's river discharges into the oceans. Thus during a lunar day the water moving in and out the Bay of Fundy is actually four times the combined discharge of all the world's rivers. During extraordinary tides this volume may exceed 146 km^3 every 6.2 hours. In effect, the energy thus channeled into the Bay creates a slow, large scale oscillation, or "seiche". Tremendous tidal amplification may occur through this near-resonant response. Here, a comparison with the pendulum movement of a grandfather clock is instructive. The visible movements of a heavy pendulum are maintained by a imperceptible downward-moving weight, keeping the pendulum going through the escapement mechanism. The oceanic tides, caused by the horizontal movements due to gravitational effects of Moon and Sun, maintain the seiche and thus the tidal movements in the Gulf of Maine - Bay of Fundy system.

The appropriate formula describing these conditions (for a open basin like the Bay of Fundy) is given by:

$$T = \frac{4L}{(g \cdot d)^{0.5}} \qquad \text{(equation 4)}$$

where T is the resonant period in seconds, L the length of the basin in metres, the acceleration of the Earth's gravity $g = 9.8$ m/sec^2, and d the depth in metres.

The exact position of the mouth of the Bay of Fundy is controversial, but it is generally located near the 75 km long line connecting Whipple Point on Brier Island, Nova Scotia, to West Quoddy Head (the easternmost point of the USA) via Machias Seal Island (Fig. 1). Actually the tidal ranges start to increase at Bar Harbor, Maine, on Mount Desert Island. In the simplest case, if one takes the length of the basin as about 270 km long and the average depth as 60 m, the period of oscillation of the Bay of Fundy seiche works out to 12 hours and 25 minutes. Greenberg (1987) calculated the period of oscillation at about 13.3 hours. Both of these cases are close to a semi-diurnal tide of 12.42 hours. However, in light of other estimates (Rao 1968, Garrett 1970), the exact resonant period of the Bay remains a controversial matter.

Resonant oscillation develops, resulting in a high tidal amplitude and a tidal range several times greater than the open ocean tide. The range of the tides in the Bay of Fundy steadily increases from the eastern end of the Jordan Basin in the Gulf of Maine (Fig. 1) to the head of the Bay, about 400 km northeast of it. Tides at Bar Harbor, with a mean range of 3.1 m, result from the increase in the mean range in the oceanic tides of 0.9 m, through the Northeast Channel and across the Gulf of Maine over a distance of 335 km. At the mouth of the Bay of Fundy the average range of the tides is 5 m, halfway into the Bay 7.3 m and at the head of Chignecto Bay, near Belliveau Village, New Brunswick, 12 m, which at times can reach 15.2 m.

At Burntcoat Head, Nova Scotia, in the Minas Basin near the head of the Bay of Fundy, the maximum range between low and high tides was observed on July 16, 1916 by Bell-Dawson, Superintendent of Tidal Surveys, being 53.43 feet (16.29 m), a world record. Here the mean range of 12.1 m is amplified about 13.5 times in relation to the oceanic tides over a distance of 735 km (Bell-Dawson 1920).

Just northeast of the Jordan Basin is a sort of threshold or sill, which at its deepest point is 160 m below the present Chart Datum. This sill runs southeast from Jonesport, Maine, over the

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Grand Manan Banks, to a submerged continuation of Digby Neck (Lurcher Shoal), 40 km southwest of Brier Island (Fig. 3). In the 55 km wide channel between Grand Manan Island and Brier Island the water depth in places exceeds 200 m. Seventy-five kilometres further into the Bay, on the line connecting Saint John, New Brunswick, with Digby Gut, Nova Scotia, the depth is less than 100 m, while off Cape Chignecto, another 85 km northeast, the depth is less than 40 m. Here the Bay splits into two sections. In the narrowest section of the Minas Channel the depths may exceed 100 m, although most of the Minas Basin has depths of less than 20 m. At Noel Head, 6.5 km east of Burntcoat Head, the Bay falls dry at low tides. However, tides reach even higher levels in the Salmon and Shubenacadie River estuaries, some 40 km east of Burntcoat Head.

In many estuaries and bays the range of the tides (twice their amplitude) increases exponentially with distance. This is the case in the Gulf of Maine - Bay of Fundy system. Thus the range at a particular location Y_2 can be estimated if the distance D (positive in the direction of the head of the Bay) from a reference station Y_1 is known. If the percentage increase P per kilometre is known, the range T at point Y_2 can be calculated with:

$$T_{Y2} = T_{Y1} \cdot (1 + P/100)^D = T_{Y1} \cdot F^D \qquad \text{(equation 5)}$$

where factor F is (1+P/100).

The importance of this relationship is illustrated for the Minas Basin. Note firstly (Table 1) that while the amplitudes of the semi-diurnal tides increase toward the head of the Bay and Basin, the mean diurnal amplitudes remain virtually constant at about 0.2 metres. Nor is it likely that they will be altered when progressing into river estuaries. However, the semi-diurnal tides are clearly a function of the distance from Saint John, where the principal tidal hydrographic station is located. This is shown in Table 2, where it is evident from the values of F (the exponential factor of the tidal increase over distance D) that the range of the semi-diurnal tides increases exponentially as they advance into the Bay, at a rate P of 0.35 %/km. This allows the local tidal range to be estimated rather accurately, with reference to the local Chart Datum. From this follow realistic estimates of Mean Water Level (MWL) and High Water level (HWL). Detailed examples of this procedure are documented in Gordon *et al.* (1985) and Desplanque and Mossman (1998).

The above relationship is, among other things, relevant to a host of legal issues concerning tidal boundary problems (Desplanque and Mossman 1999a) and engineering projects such as proposed tidal power schemes in the Bay of Fundy (Gordon and Dadswell 1984).

The importance of diurnal inequalities

Tides are generally semi-diurnal, *i.e.* there are two High Waters (HW) and two Low Waters (LW) during a day, be it solar or lunar. The strength of tides is mainly modified by changing distances between Earth and Moon, and also because the Sun and Moon act individually from varying directions. Changing declinations of the Moon and Sun with respect to the plane of the Earth's equator cause diurnal variations in the strength of the tides. As seen from the Earth, the Sun appears to move through the plane of the ecliptic, which makes an angle of 23.452° with the equator. In fact the Earth revolves once a year through its orbit around the Sun, located in the ecliptic (Fig. 4). When the Sun is overhead at local midday at the equator on March 21 and September 23, the event is termed an equinox, and the length of the day and night are the same everywhere on earth. The Sun is said to have a north declination between the spring and fall equinoxes, and a south declination during the remainder of the year. It reaches its maximum north declination of 23.452° at the summer solstice in June.

The Moon goes through a similar but much shorter declinational cycle, lasting 27.322 days. Also, because the Moon's orbital plane is at an angle of 5.145° to the ecliptic, its declination is more variable than that of the Sun. Thus the maximum declination of the Moon to the Earth's equatorial plane ranges from 28.597°N to 28.597°S 14 days later. Halfway through its nodical cycle, 9.3 years later, the range of the Moon's declination is reduced from 18.307°N to 18.307°S.

As detailed in Fig. 5, the phenomenon of diurnal inequality translates in practice to a difference in height between the two High Waters and/or the two Low Waters each tidal day. The strongest diurnal inequality is possible when spring tides (at Full and New Moon) occur during the solstices (June and December), when both celestial bodies are near their maximum declination, and acting together. In the Bay of Fundy, the Higher High Water (HHW) in spring and summer (between March and September) occurs during the nighttime (6 p.m. to 6 a.m.) and during the fall and winter (September to March) during the daytime. For the same reason Lower Low Water (LLW) occurs in spring and summer between midnight and noon (morning) and during fall and winter between noon and midnight (afternoon and evening).

A sketch of the results of specific diurnal inequalities for locations in Maritime Canada serves to highlight details of the Fundy tides (Fig. 6). The combined effect of the semi-diurnal constituents can be visualized as a wave, with nearly two cycles/day moving through the area, whereas the combined diurnal constituents form a wave passing through a location once a day. If the High Water of the latter combines with one of the semi-diurnal High Waters, the result will be an extra high tide (Schureman 1941). However the diurnal Low Water will then coincide with the next semi-diurnal High Water, reducing it in strength. The two semi-diurnal Low Waters will occur when the diurnal tide is at Mean Water Level, resulting in two Low Waters of equal height. This combination occurs in the Gulf of Saint Lawrence, along the north shore of Prince Edward Island, and along the eastern shore of New Brunswick (Fig. 6, case 1). Here the two daily High Water are unequal and the two Low Waters equal. When the Moon is close to the equatorial plane, High Waters are also equal for a day or so.

The reverse applies in the Northumberland Strait, where the High Waters are equal and the Low Waters unequal (Fig. 6, case 2). Here, one of the semi-diurnal Low Waters coincides with the diurnal Low Water. In fact at times in sections of this area the semi-diurnal tide is so weak that the amplitude of the diurnal wave is more than twice that of the semi-diurnal amplitude. For example, in the western section of Northumberland Strait near Shediac Bay and Escuminac only one High Water and one Low Water may occur during the lunar day.

The situation concerning diurnal inequalities in the Bay of Fundy is detailed in Fig. 6, case 3. This illustrates the case when the midpoint of the falling diurnal wave coincides with one of the midpoints of a rising semi-diurnal wave. The result is that a Lower High Water (LHW) is followed respectively by a Higher Low Water (HLW), a Higher High Water (HHW) and a Lower Low Water (LLW). Thus in the Bay of Fundy the sequence over a lunar day is typically:

HHW - LLW - LHW - HLW - HHW

The characteristic behaviour of the Fundy tides over the course of a month is shown in Fig. 7 for Herring Cove in Fundy National Park, New Brunswick. Compared with marigrams from other localities in the Canadian Maritimes provinces, the diurnal inequalities of the Bay of Fundy are relatively modest.

Tides at Herring Cove (Fundy National Park)

Tidal variations in the Bay of Fundy throughout the year are well illustrated by a typical annual record of tide levels at Herring Cove in Fundy National Park, New Brunswick. The port of Saint John, 89 km more seaward, serves as reference port because the tides throughout the Bay of Fundy all show virtually the same features, except for the ranges of the local tides. The tide levels can be estimated from the tidal predictions for Saint John, New Brunswick (T_{SJ}), as given in the Tide and Current Tables published by the Canadian Hydrographic Service. The following equation is used to convert the given predicted levels of T_{SJ}, measured in feet from the local Chart Datum (*i.e.* the lowest normal tide) to levels T_{HC} measured in metres from Mean Water Level at Herring Cove.

$$T_{HC} = (T_{SJ} - 14.5) \cdot (1.0035)^{89} \cdot 0.3048m \quad \text{(equation 6)}$$

where 14.5 feet is the height of local mean water level above chart datum at Saint John.

Figure 8 illustrates the variations that occurred during the 706 tidal cycles in 1988. On most days there are two High Waters and two Low Waters, being the highest and lowest levels predicted. The levels are measured from Mean Water Level (MWL) that the water surface would assume if no tide-producing gravitational influences of Moon and Sun were present. In that case the only differences in water levels would be caused by variation in barometric pressures, wind speed and direction, water temperature and other meteorological conditions.

If the combined gravitational influences of Moon and Sun remained constant, the tidal fluctuations would also remain constant. High waters would reach 4.1 m above Mean Water Level and low waters would drop 4.1 m below it. However, the influences of the Moon and Sun do not remain constant, neither in strength nor direction. This causes variations in the strength of the local tides.

As noted earlier there is generally a marked difference (diurnal inequality) in the levels reached by the two daily tides in the Bay of Fundy. This diurnal inequality is accentuated by connecting the successive nighttime tide levels with a solid line. Note that the High and Low Waters occurring during the day time are generally quite different from those that occur during the nighttime (6 p.m.-6 a.m.). Thus, during the spring and summer (*i.e.* between the equinoxes in March and September) the High Waters during the daytime are lower than during nighttime. The reverse is true during fall and winter when High Waters during the daytime are higher than during the nighttime.

Although beyond the scope of this paper, tidal patterns generally are irrevocably linked to ecology and the life cycles of many organisms, just as they are to important physical processes (through the seasons) such as tidal currents and cycles of erosion and sedimentation (Thurston 1990, Fader *et al.* 1996, Greenberg *et al.* 1997). Thus, for instance, the shape of the curved erosional indentations in the rocky shoreline at "The Rocks" in the provincial park at Hopewell Cape, New Brunswick, are a true reflection of the total time the water surface is situated at certain levels throughout all tide cycles (Desplanque and Mossman 1998, Trenhaile *et al.* 1998).

At Herring Cove the difference in level reached by the daily tides can be as much as 0.86 m for High Waters and 0.78 m for Low Waters. This occurred in January, July and December 1988, close to the solstices. But these differences disappear every two weeks as indicated where the HHW and LHW curves on Fig. 8 intersect, as well as the LLW and HLW curves.

It is instructive to note here the three main astronomical reasons for these fluctuations:

1. Variable distance between Moon and Earth. This causes the greatest deviations from the average (mean) tide in the Bay of Fundy. Because the Moon's orbit is elliptical, once a month at perigee the Moon is closest to the Earth, and thus its gravitational pull the greatest, resulting in stronger than average tides. These so-called "perigean" tides recur every "anomalistic month" of 27.555 days. The dates when the Moon is in perigee (P) and apogee (A) are indicated on Fig. 8.

2. Variable celestial positions of the Moon, Sun and Earth relative to each other. The cycle of the Moon's phases in which there are two sets each, of "spring" and "neap" tides is the "synodical month" of 29.531 days (Fig. 9). In the first set, the Earth is either between the Sun and Moon (full moon) or the Moon is between Earth and Sun (new moon). This is the time that the spring tides occur, meaning tides stronger than average. A week later the Moon is positioned at right angles to the Sun and its gravitational influence weakened by the Sun's gravitational forces acting in a different direction. The tides are then weaker than usual and are called neap tides. They coincide with either the First or Last Quarter phases of the Moon (Fig. 8).

The dates on which the different lunar phases occur are plotted on Fig. 8. One can expect stronger than usual tides a few days later than Full and New Moon, and weaker tides near the Quarter phases of the Moon. There is a certain inertia in the development of the tides, analog to the fact that the months of July and August are on average warmer in the northern hemisphere than June, when the days are longer and the Sun is higher. For this reason the highest tides occur a few days after the astronomical configurations which induce them.

3. Declination of the Moon and Sun relative to the Earth's equator. Declination is the angular distance in degrees between a heavenly body and the celestial equator (the plane in which the Earth's equator is situated) when it passes through the local meridian. A complete cycle, in which the Moon crosses the equator twice, lasts 27.322 days and is called a "tropical month".

As noted earlier the angle of maximum declination of the Moon is constantly changing. Over a 18.6 cycle it varies between 18.3° and 28.6°. Thus the situation depicted in Fig. 8 will not be duplicated until 2005 A.D. In 1987 the Moon's declination reached its maximum value. On December 6, 1987, the Full Moon was as high above the horizon as it could be. When the Moon is exactly above the equator, there will be no difference in strength of the two daily tides (no diurnal inequality). This will happen every 13.6 days. But the inequality will soon reappear and will be strongest 7 days later, when the Moon is either in its most northerly or southerly declination.

The dates when the Moon is passing over the equator are given on Fig. 8, and also the dates when the most northerly and southerly declinations are reached. Since the New Moon is never more than 5° different from the Sun's declination, there is a close relationship between the Sun's declination, the phase of New Moon and its declination. Because of this fact, the maximum diurnal inequality is centred around spring tides in June and December, and the weakest inequality during neap tides in March and September. When the perigean and spring tides coincide in June and December, the diurnal inequality causes one of the daily tides to be extra strong. This phenomenon, when combined with storm conditions presents grave risks of destruction for property owners and settlements along the coastal zone (Taylor *et al.* 1996, Desplanque and Mossman 1999b). This was proven most recently on January 21, 2000, when strong northeasterly gales added to these conditions in the southeastern section of the Gulf of St. Lawrence and Northumberland Strait, to produce record high tides. Coastal installations were severely damaged and some homes were lifted from their basement walls and moved several hundreds of metres by the incoming tide.

Figure 8 shows that at Herring Cove in 1988 perigean tides coincided with one of the month's set of spring tides around February 19. Perigee occurred on February 17 at 11:00 AST, while the New Moon occurred on the same day. One of the highest tides (5.53 m+MWL) of the year was expected with a delay of 48 hours shortly after noon on February 19. On the same day the water was predicted to drop to its lowest level (5.87 m-MWL). On April 25, when apogee coincided with a quarter phase of the Moon, the water dropped shortly after midnight to 2.79 m below Mean Water Level.

One might expect the lowest High Water levels near the days that apogee coincided with one of the Quarter phases, as on May 23 or December 1, when the water was expected to reach levels of 3.20 m+MWL. This is considerably higher than the predicted level of 2.70 m+MWL on February 12, March 12 or August 22, 1988. The explanation is that the first two dates were close to zero declination with nearly equal High Waters, while the latter three were close to maximum declination with 0.7 m diurnal inequality.

Recall that on February 19 there was a strong tide, caused by perigee and New Moon, but that two weeks before or after this date the spring tides coinciding with Full Moon were rather weak, not much higher than average tides. This is because the Moon was at apogee.

The same situation repeats itself after about 6 and 7 months when in September and October the Full Moon occurs close to perigee. The cycle when peaks of perigean tides coincide with spring tides is 206 days. This situation occurs all over the world. It just happens to be far more pronounced in the Bay of Fundy because of the great tidal range. On September 27 the peak reached a level of 5.49 m+MWL. Two of these cycles last 412 days, meaning that each year the date that perigean tides are close to Full Moon is 47 days or about 1.5 month later on the calendar. This shift means that extra strong tides in the Bay of Fundy can occur during all seasons, depending on the year of observation. The record at Herring Cove (Fig. 8) shows that halfway through this period of 206 days, the Moon was at its mean distance from the earth during both New and Full Moon, and spring tides in June and July were of equal strength. But at the same time perigee was coinciding with one of the neap tides, making it much stronger than the preceding and following neap tides.

Overall there is a rather close correspondence between the high tides predicted on the basis of astronomical conditions and those observed. This is illustrated in Fig. 10 which reveals the cyclic behaviour of the tides at Saint John, New Brunswick, over a twenty year period. Exactly the same phenomena are mirrored in the tidal behaviour at Herring Cove.

As we have seen, Fundy tides are quite distinct from the tides in the Gulf of Saint Lawrence and much stronger than those observed along the shores of the Atlantic Ocean. Although beyond the scope of this paper to elaborate, the Bay of Fundy tides rule over the ecology of the region and a whole host of physical and chemical processes, the most evident of which are perhaps those of erosion and sedimentation. An integral part of a much larger system, the tides are connected through the Gulf of Maine and across Georges Bank to the North Atlantic tidal regime.

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Table 1. Constituents in the Gulf of Maine and the Bay of Fundy (in metres). SD = average amplitude of semi-diurnal tides; DL = average amplitude of diurnal tides.

Major Constituents of the Tides in the Bay of Fundy										
	M2	S2	N2	K2	(SD)	K1	P1	O1	(DL)	K4
Atlantic Ocean										
Station 22B	0.441	0.090	0.112		0.45	0.075		0.209		
Gulf of Maine										
Portland	1.353	0.213	0.289	0.057	1.38	0.146	0.044	0.155		0.063
Pulpit Harbor	1.492	0.237	0.320	0.065	1.49	0.139	0.047	0.111		0.007
Bar Harbor	1.546	0.253	0.356		1.58	0.140		0.110		
Eastport	2.613	0.426	0.526	0.116	2.67	0.146	0.044	0.115		0.063
Bay of Fundy										
Saint John	3.076	0.503	0.659	0.143	3.14	0.153	0.049	0.119	0.18	0.057
Partridge Island	3.085	0.509	0.597	0.137	3.14	0.162	0.055	0.107	0.18	0.040
Cape Blomidon	5.029	0.732	1.006	0.198	5.11	0.162	0.055	0.116	0.18	0.046
Parrsboro	5.051	0.753	0.847	0.204	5.12	0.192	0.073	0.128	0.21	0.091
Five Islands	5.400	0.831	1.129	0.226	5.51	0.181	0.058	0.129	0.20	0.023
Hantsport	5.665	0.847	0.722	0.236	5.73	0.209	0.065	0.152	0.24	0.192
Burntcoat Head	5.642	0.832	1.097	0.226	5.73	0.143	0.049	0.122	0.18	0.101

Table 2. Relationship between tidal magnitude and distance, the latter measured from Bar Harbor (Y_1), Maine. The range of the dominant semi-diurnal tides in the Bay of Fundy increases exponentially at the rate of bout 0.35 % per kilometre from the edge of the continental shelf, via Bar Harbor into the Bay. R is the ratio between the semi-diurnal tides at the tidal stations, compared with those of Bar Harbor. F is the exponential factor of tidal increase over distance. Note that the two stations (Portland and Pulpit Harbor) west of Bar Harbor in the Gulf of Maine hardly differ in strength (F).

Exponential Growth of the Bay of Fundy Tides

	Distance D km	(SD)(Y_2)m	R=Y2/Y1	F=R(1/D)
Atlantic Ocean				
Station 22B	-333	0.45	0.285	1.00377
Gulf of Maine				
Portland	-175	1.38	0.873	1.00078
Pulpit Harbor	-61	1.49	0.943	1.00096
Bar Harbor (Y_1)	0	1.58	1.000	
Eastport	120	2.67	1.690	1.00438
Bay of Fundy				
Saint John	195	3.14	1.987	1.00353
Partridge Island	195	3.14	1.987	1.00353
Cape Blomidon	328	5.11	3.234	1.00358
Parrsboro	334	5.12	3.241	1.00353
Five Islands	353	5.51	3.487	1.00354
Hantsport	360	5.73	3.627	1.00359
Burntcoat Head	372	5.73	3.627	1.00347

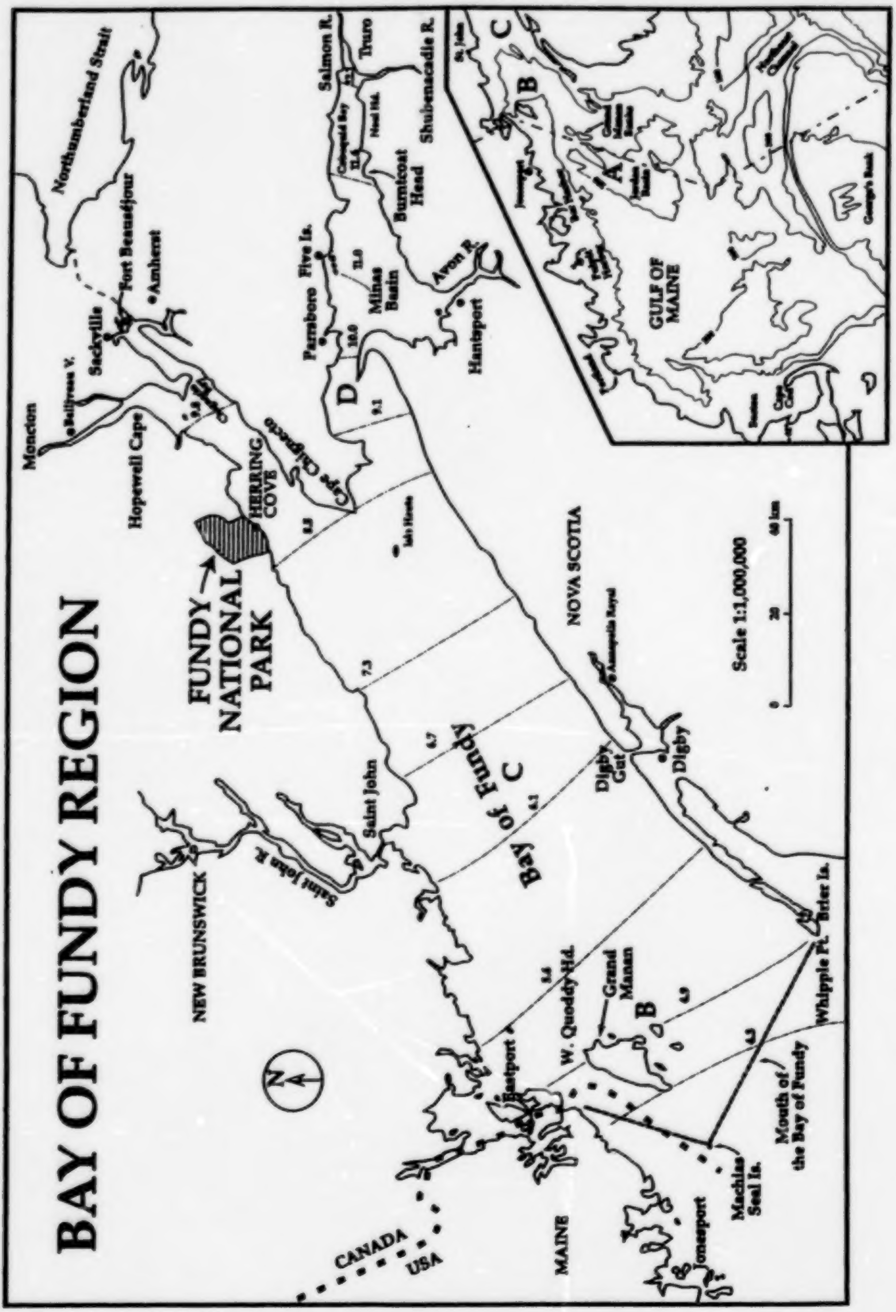
BAY OF FUNDY REGION
FUNDY NATIONAL PARK
HERRING COVE
NEW BRUNSWICK
NOVA SCOTIA
MAINE
CANADA
USA
Bay of Fundy
C
B
D
Northumberland Strait
Fort Beausejour
Amherst
Sackville
Moncton
Petitcodiac R.
Hopewell Cape
Cape Chignecto
Parrsboro
Five Is.
Minas Basin
Cobequid Bay
Salmon R.
Truro
Noel Hd.
Shubenacadie R.
Burntcoat Head
Avon R.
Hantsport
Isle Haute
Annapolis Royal
Digby Gut
Digby
Saint John
Saint John R.
W. Quoddy Hd.
Grand Manan
Eastport
Brier Is.
Whipple Pt.
Mouth of the Bay of Fundy
Machias Seal Is.
Jonesport
Scale 1:1,000,000
0
20
40 km
GULF OF MAINE
Georges Bank
A
7.3
8.1
10.0
11.6
8.7
7.3
6.7
6.1
5.8
4.9
4.3

Figure 1. Location map of the Bay of Fundy and inset showing Gulf of Maine indicating various features and place names. The mean tidal range is given in metres at locations shown by broken lines.

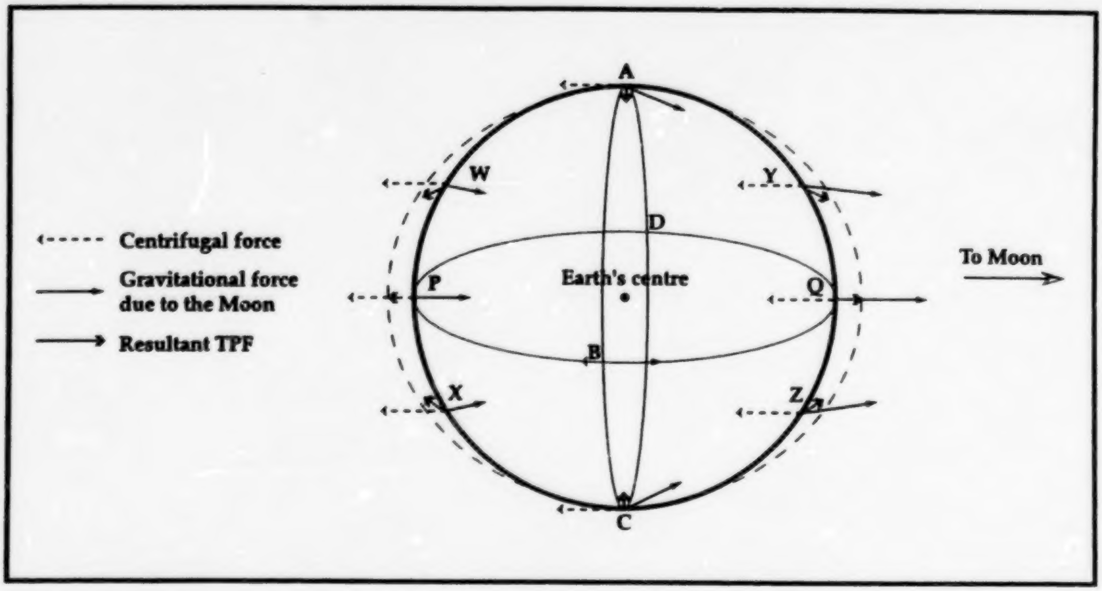
A
W
Y
D
Centrifugal force
Gravitational force due to the Moon
Resultant TPF
P
Earth's centre
Q
To Moon
B
X
Z
C

Figure 2. The centrifugal force has the same magnitude and direction at all points. Gravitational force exerted by the Moon on Earth varies in magnitude inversely with the square of the distance to the Moon and direction (towards the centre of the Moon). The tide-producing force (TPF) at any location (P) is the resultant of centrifugal and gravitational forces at that point and varies inversely with the cube of the distance from the Moon. The alleged ocean's response to TPF, according to the tidal equilibrium theory, is shown by broken lines.

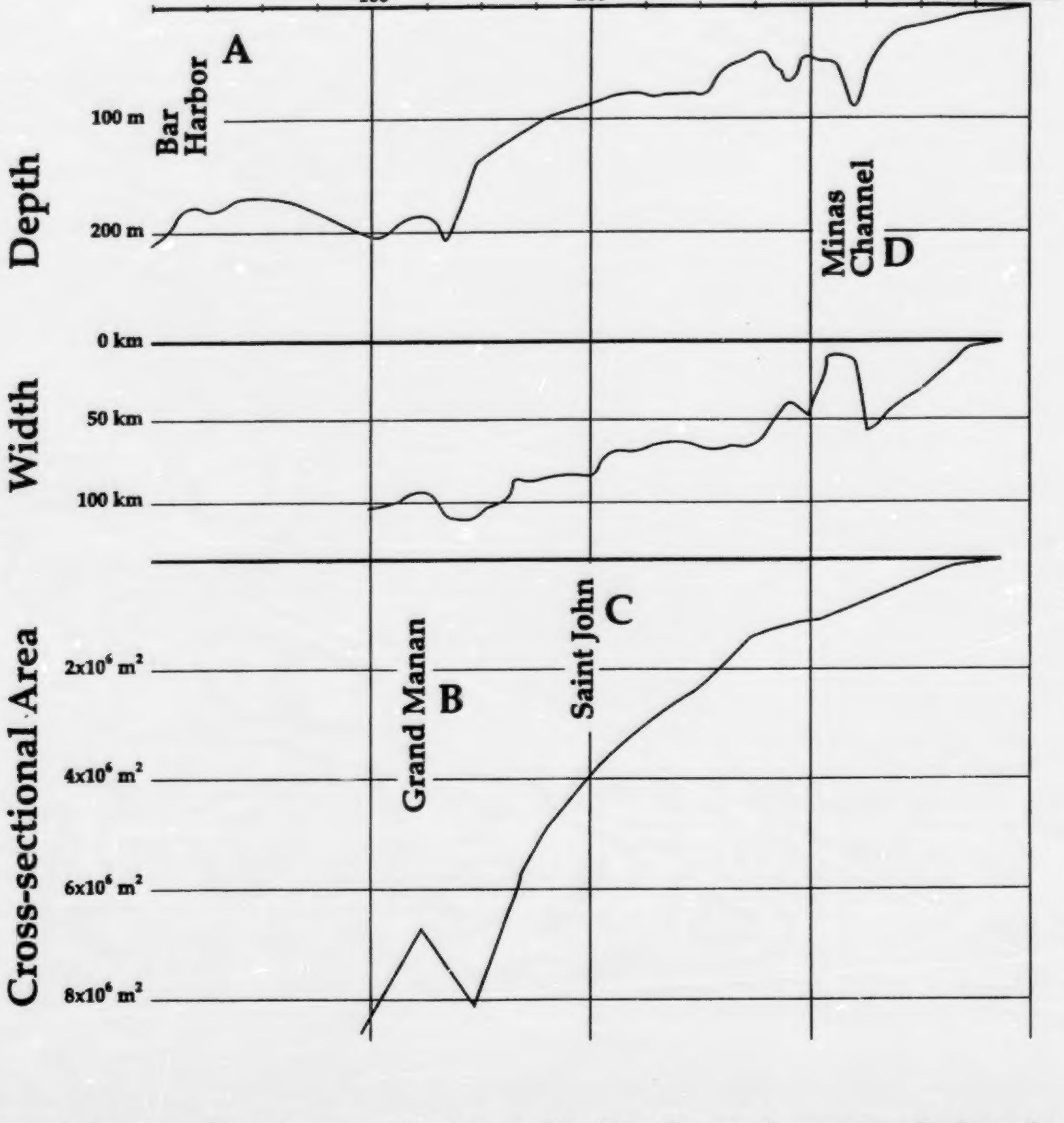

Figure 3. Depth profile and cross-sectional areas of the Bay of Fundy drawn perpendicular to the line of section ABCD (in Fig. 1) from Bar Harbor (0 km) northeast to the head of Cobequid Bay.

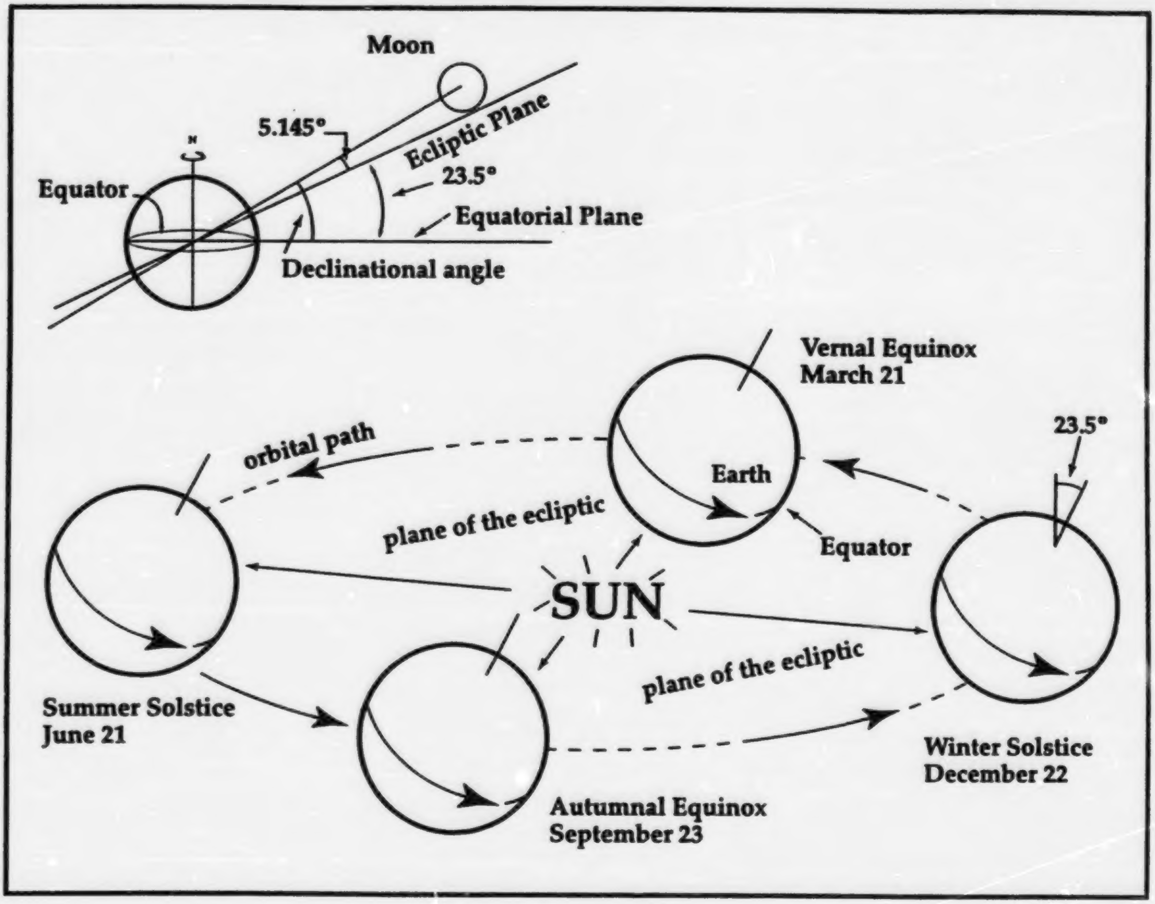
Moon
5.145°
Ecliptic Plane
N
Equator
23.5°
Equatorial Plane
Declinational angle
Vernal Equinox
March 21
23.5°
orbital path
Earth
plane of the ecliptic
Equator
SUN
plane of the ecliptic
Summer Solstice
June 21
Winter Solstice
December 22
Autumnal Equinox
September 23

Figure 4. Earth's equator makes an angle of about 23.5° (actually 23.452°) to the plane (ecliptic) in which it moves around the sun. The noonday sun at the summer solstice stands over 23.5° N latitude, and at the winter solstice over 23.5° S latitude. Adding to Earth's tilt, the Moon is at an angle of about 5° to the ecliptic. The monthly swing was 57.2° during November 1987 but decreased to 36.6° in February 1997, only to increase again to 57.2° over the following 9.3 year period. Thus, the amount of (maximum) declination of the moon's orbit is constantly varying.

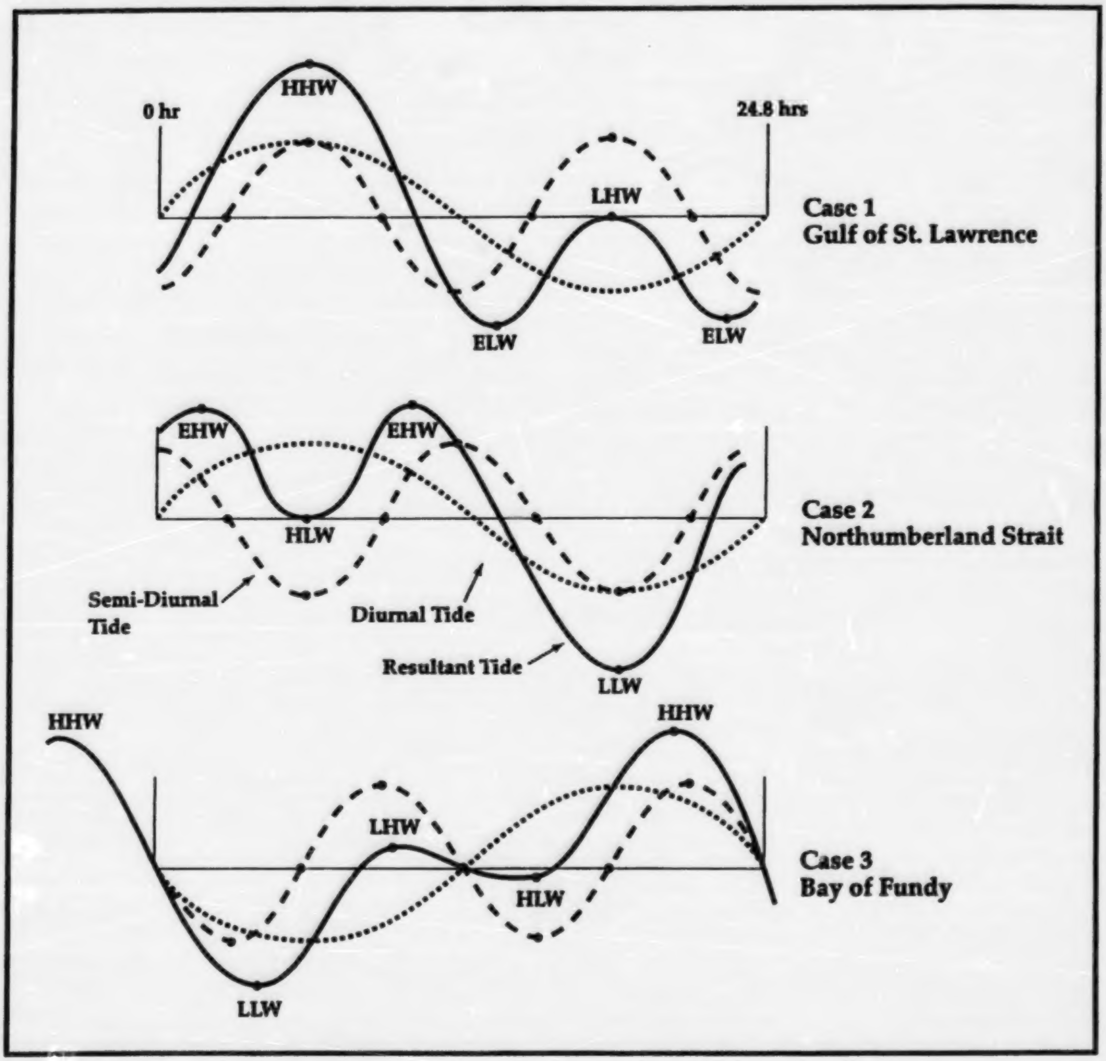
0 hr
24.8 hrs
HHW
LHW
ELW
ELW
Case 1
Gulf of St. Lawrence
EHW
EHW
HLW
Case 2
Northumberland Strait
Semi-Diurnal Tide
Diurnal Tide
Resultant Tide
LLW
HHW
HHW
LHW
HLW
Case 3
Bay of Fundy
LLW

Figure 5. The development of diurnal inequalities in Bay of Fundy tides.

In theory tidal "bulges" move westward on about the same latitudes around the Earth in 24.8 hours, the latitude of the circles matching the declination of the Moon.

Assume that at noon, June 21, there is a solar eclipse over the Greenwich meridian. At this time, the centre of one bulge would be at 23.5° N latitude, 0° longitude, the other bulge at 23.5° S at the 180° meridian. In theory, the bulge should be over the Fundy area (65° West) around 16:00 hr GMT (i.e., around noon, local time). (A) Observations in the Bay of Fundy however will show that on that day the HHW will occur at midnight (24:00 hr) and HLW around 18:00 hr. The peak of the diurnal inequality will occur at around 21:00 hr, or about 9 hours later than the theoretical time. The same situation occurs when there is a lunar eclipse (Full Moon) on the same day in June. (B)

The situation would be different during a solar eclipse on December 23. A "bulge" would then occur around midnight north of the equator on the dark side of the Earth. However, the peak of the diurnal tide in the Bay of Fundy would be around 9:00 hr, with HLW around 6:00 hr, and HHW around noon (12:00 hr). (C)

An almost similar situation will occur in June and December with every New and Full Moon phase. The declination of the Moon in June and December will not be exactly 23.5°, but can be anywhere between 18.5° and 28.5°, more than enough to cause a local diurnal inequality. (D)

During the equinoxes (March and September) the Sun is in the plane of the Earth's equator and the Moon crosses this plane around the same date. At such time there will be little diurnal inequality. (E)

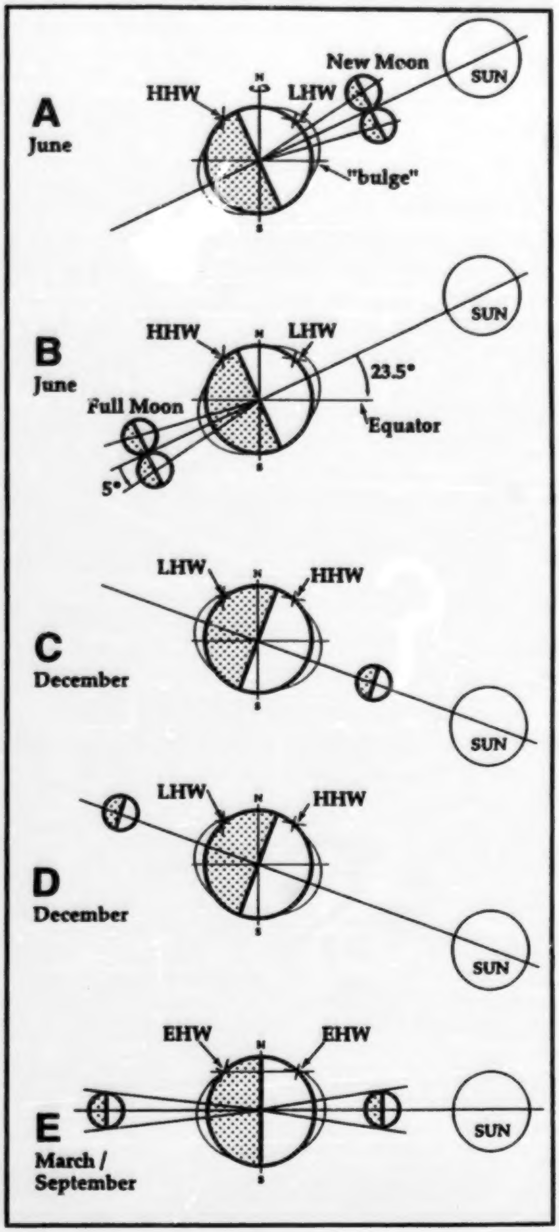

Figure 6. Rough sketch showing the combined effects of diurnal and semi-diurnal tides for: Case 1- Gulf of St. Lawrence, north of Prince Edward Island, and eastern shore of New Brunswick; Case 2- Northumberland Strait; Case 3- Bay of Fundy (greatly exaggerated). Abbreviations: HHW = Higher High Water; ELW = Equal Low Water; LLW = Lower Low Water, etc. Diurnal tide ····; semi-diurnal tide - - - - - ; sum —— .

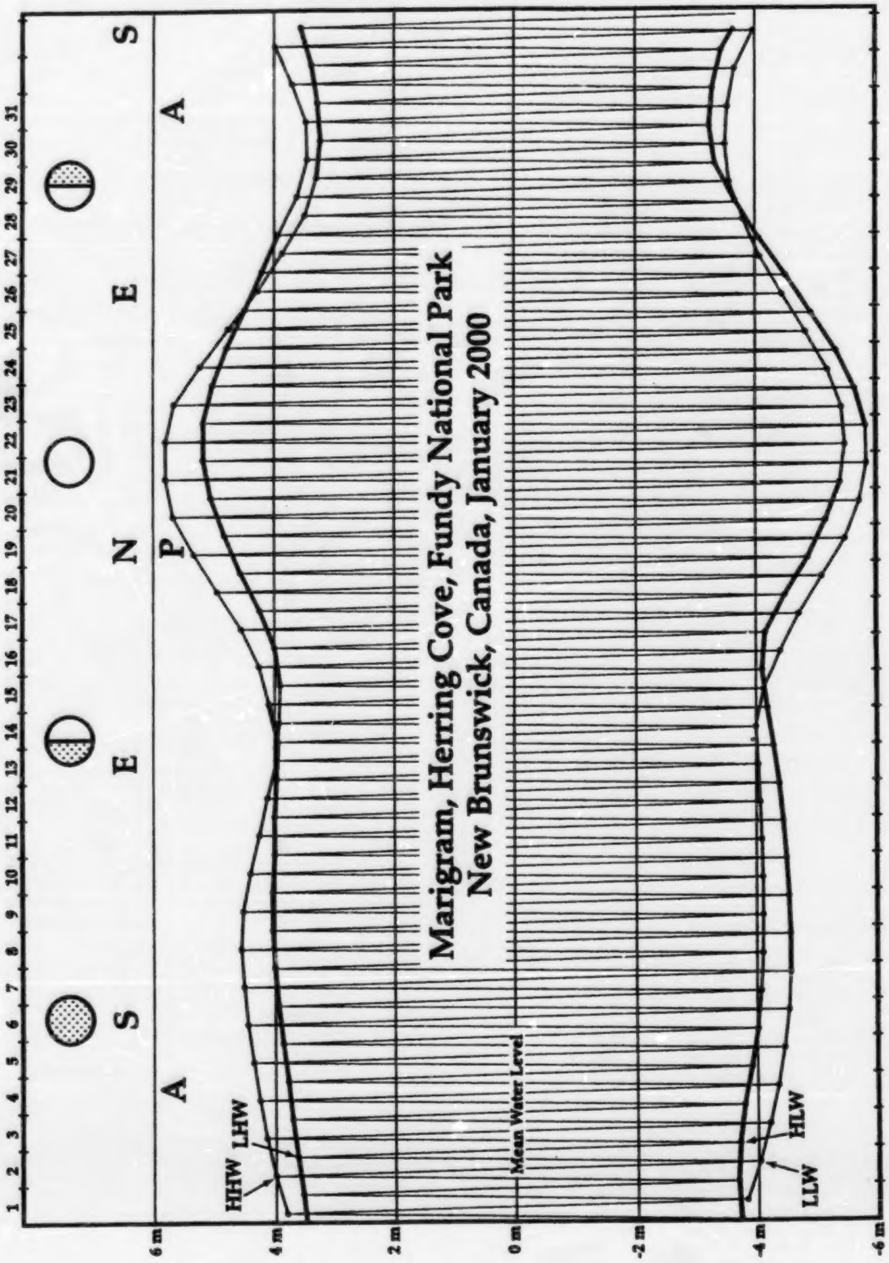

Figure 7. Marigram of typical monthly tidal cycle at Herring Cove, Fundy National Park, New Brunswick, January, 2000. Heavy lines indicate nighttime tides (HW and LW between 1800 and 0600 hours AST), lighter lines daytime tides (HW and LW between 0600 and 1800 hours AST).

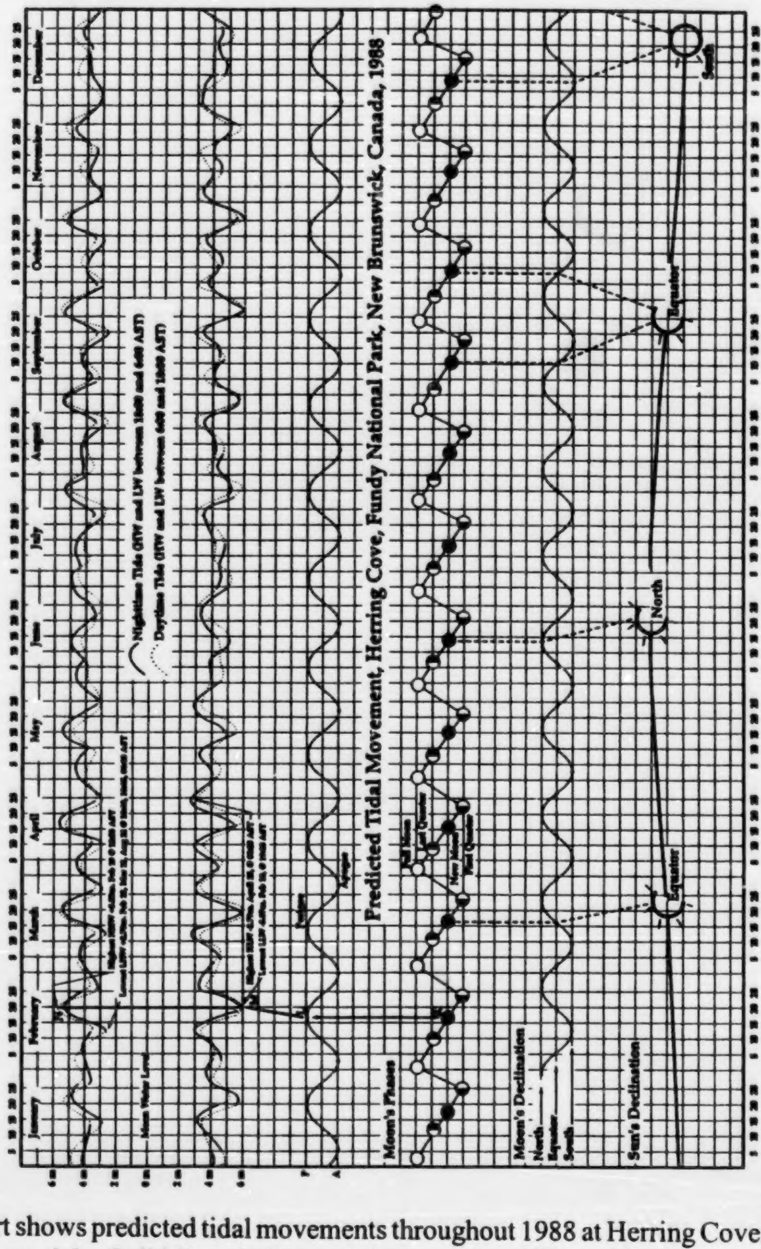

Figure 8. Chart shows predicted tidal movements throughout 1988 at Herring Cove, Fundy National Park, New Brunswick. Solid lines indicate nighttime tides (HW and LW between 1800 and 0600 hours AST). Daytime tides shown by dotted lines (HW and LW between 0600 and 1800 hours AST). Moon's distance phases and declination, and Sun's declination are shown. Note (KLMN) the coincidence of Full Moon and Perigee just before the year's highest (and lowest) tides on February 19th.

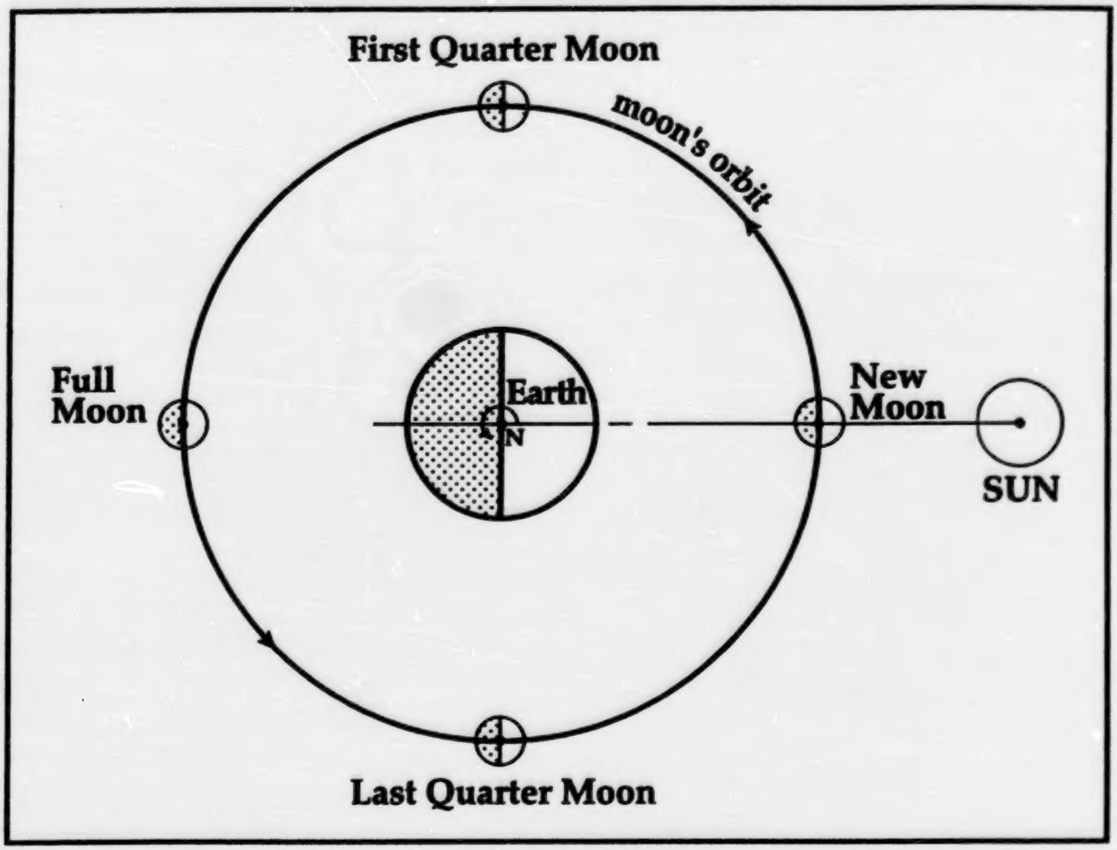
First Quarter Moon
moon's orbit
Full Moon
Earth
N
New Moon
SUN
Last Quarter Moon

Figure 9. During its elliptical orbit (here simplified to circular) about the Earth, the various phases of the Moon define the spring and neap tidal conditions. Spring tides result when Earth, Moon and Sun are aligned during Full and New Moon. Neap tides occur during the Moon's first and last quarters. The largest spring tides occur when the Moon is at its closest approach (perigee) to Earth.

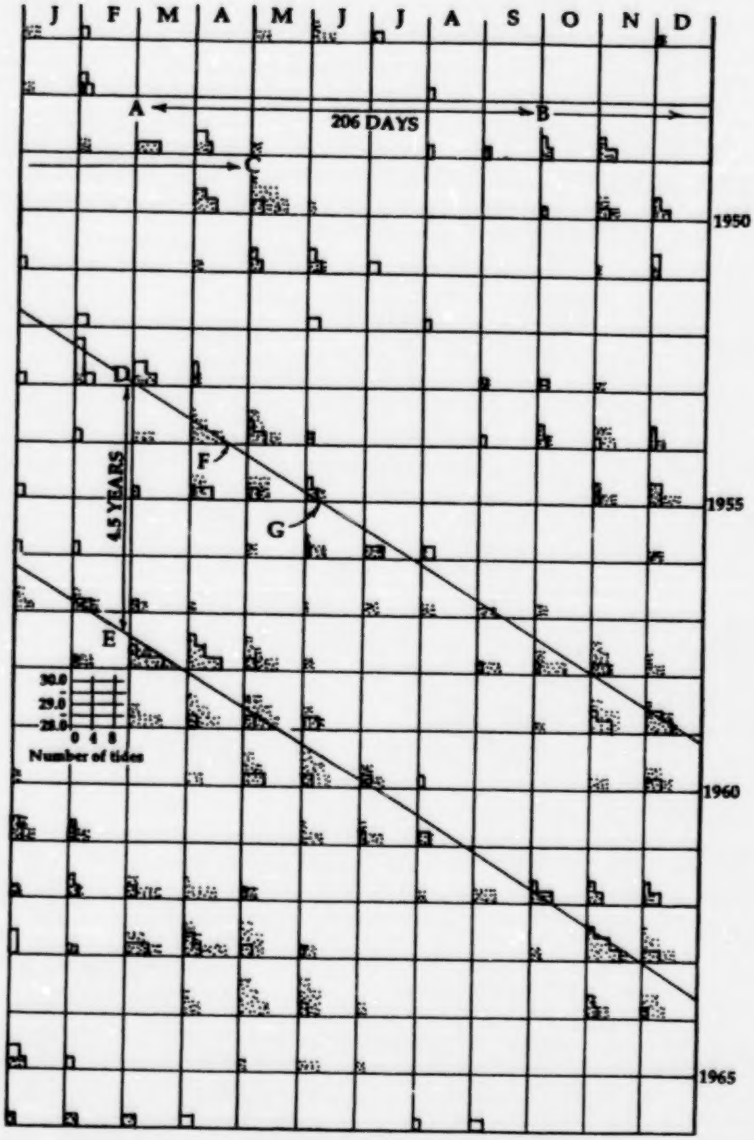

Figure 10. Number of predicted (dotted areas) vs. observed (areas enclosed by solid blocks) extreme High Waters per month at Saint John, New Brunswick, for the interval 1947 to 1966. Cyclic behaviour of the tides is indicated by the 206 day (7 month) perigee/spring tide cycle (A to B), and at 4.5 years (D to E, vertically) and its matching at 14 month (A to B to C), and at 18 year intervals. Also shown is the number of tides that reached 28.0 feet (8.5 m) and higher, above Chart Datum. Note how the peaks are shifted 48 days (F to G - where the sloping lines cross the horizontal axis) to a later date each year.

TIDAL BARRIERS IN THE BAY OF FUNDY: ECOSYSTEM IMPACTS AND RESTORATION OPPORTUNITIES

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In 1999, concern for the cumulative impacts of Bay of Fundy tidal barriers converged to create a critical mass for action. Environment Canada published a report by Peter Wells entitled "Environmental Impacts of Barriers on Rivers Entering the Bay of Fundy: Report of an *ad hoc* Environment Canada Working Group", documenting the extent of dams and causeways on Fundy rivers, and outlined their known and postulated environmental impacts. Also, BoFEP published Jon Percy's factsheet "Wither the Waters?"

The Conservation Council held a workshop in April to consider 1) the impacts described by Dr. Wells' report; 2) several examples of removals or openings of tidal barriers; and 3) opportunities for ameliorating the impacts of barriers in the Bay of Fundy. Research, policy and restoration recommendations were developed by participants. The CCNB has since advanced two recommendations: 1) a project to inventory and assess small barriers (*i.e.* road crossings, dykes) is underway; 2) we have developed and are advancing draft text for a Federal-Provincial Accord on Restoring Tidal Flow in the Bay of Fundy.

CONDITIONS FOR DIADROMOUS FISH PASSAGE AT THE PETITCODIAC RIVER CAUSEWAY

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Abstract

The Petitcodiac River Causeway, constructed in 1968 as a transportation link between Moncton and Riverview, New Brunswick, forms a physical barrier to fish migrating between marine and freshwater portions of the river system. Over half the fish species formerly recorded from the freshwater portion of the river are diadromous, and most have been adversely affected by the causeway, which blocks the estuary about 24 km below the former head of tide. Prominent species that have been reduced or eliminated from the system include Atlantic salmon (part of the genetically distinct Inner Bay of Fundy stock), sea-run brook trout, American shad, striped bass and rainbow smelt. Over the past three decades, operating procedures of the control gates and the configuration of the vertical-slot fishway have been modified several times in attempts to improve fish passage. Eventually, gate operating procedures of the 1980s and 1990s will be statistically analysed using the gate operator's logbook data in order to evaluate the historical fish passage opportunities of all diadromous species recorded from the system. Here, I review some relevant history.

What species require passage?

Diadromous species require migration between freshwater rivers such as those in the Petitcodiac system and marine waters such as the Bay of Fundy to complete their life cycles. In order to enter or leave the fresh waters of the Petitcodiac, diadromous species must transit the area where the causeway is now located.

Diadromous taxa clearly dominated the ecology and fisheries of the Petitcodiac, in the days before the causeway (Table 1).

Table 1. Pre-causeway fish species list.

	Diadromous	*Freshwater*
Fished - Commercial, Recreational Or Both	Alewife Blueback herring American shad Rainbow smelt Atlantic salmon Brook trout Atlantic tomcod American eel Striped bass Sturgeon (species?)	Brook trout White perch
Not fished	Sea lamprey Threespine stickleback Fourspine stickleback	White sucker Creek chub Lake chub Blacknose dace Northern redbelly dace Blacknose shiner Golden shiner Banded killifish Ninespine stickleback

What migrations occur(red)?

In general, fish undertake seasonal migrations between fresh and salt water for spawning, feeding, or overwintering. Fish that spawn in fresh water need upstream passage past the causeway for spawners, downstream passage for spent fish, and downstream passage for larvae or juveniles.

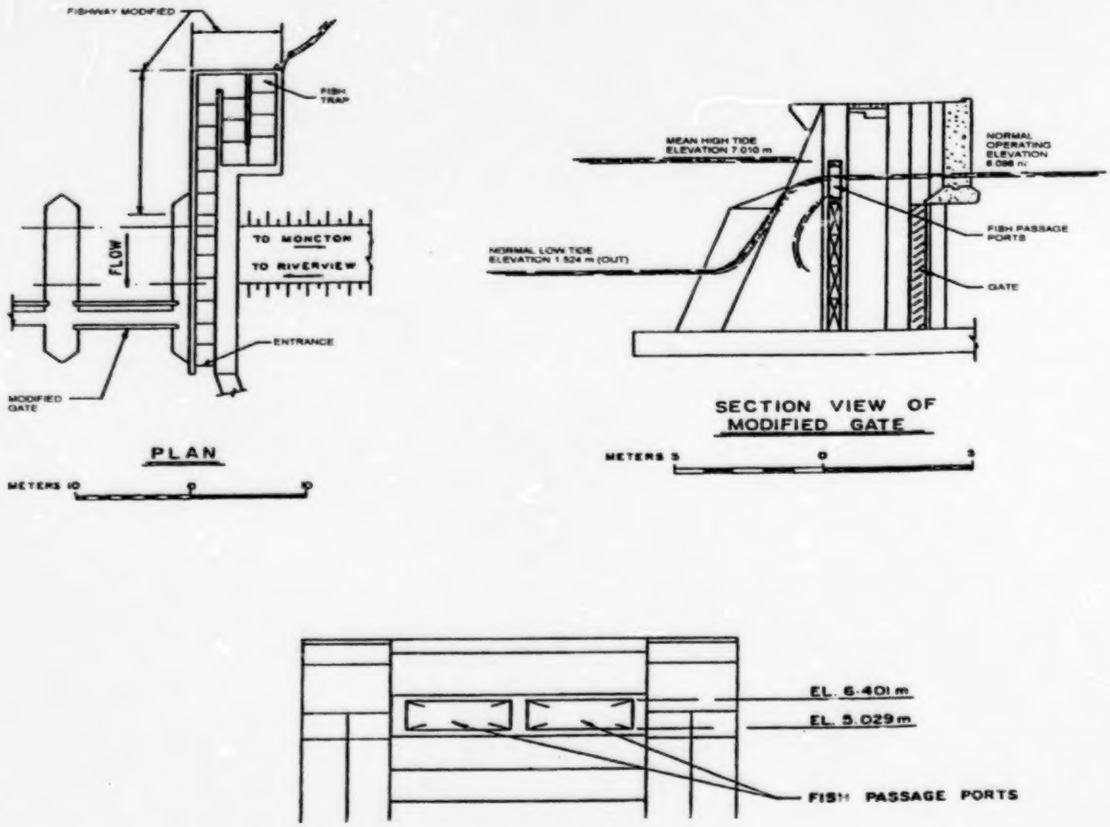
There is good evidence from the literature that the following migrations took place in the Petitcodiac system (Table 2). Note that the annual habits of some species may have involved two or more round trips between salt and fresh water, transiting the area where the causeway is now located.

Table 2. Fish migrations formerly recorded in the Petitcodiac estuary.

Fish species	Purpose of migration		
	Spawn	Feed	Overwinter
Sea lamprey	X		
Alewife	X		
Blueback herring	X		
American shad	X	X	
Rainbow smelt	X		
Atlantic salmon	X		
Brook trout	X	X	
Atlantic tomcod	X		
American eel	X	X	X
Striped bass	X	X	?
Threespine stickleback	X		
Fourspine stickleback	X		
Sturgeon (species not indicated)		X	

What are the fish passage opportunities?

The causeway was built with a vertical-slot fishway. It was apparent almost immediately that this fishway was not working well. Over the past three decades, the fish passage facilities have been modified repeatedly in attempts to improve their efficiency. The current configuration includes the modified vertical-slot fishway and a pair of "surface ports" in the gate closest to the fishway (Fig. 1).



PLAN

SECTION VIEW OF MODIFIED GATE

FISHWAY MODIFIED
FISH TRAP
FLOW
TO MONCTON
TO RIVERVIEW
ENTRANCE
MODIFIED GATE
METERS 10 0 10
MEAN HIGH TIDE ELEVATION 7.010 m
NORMAL OPERATING ELEVATION 6.096 m
NORMAL LOW TIDE ELEVATION 1.524 m (OUT)
FISH PASSAGE PORTS
GATE
METERS 3 0 3
EL. 6.401 m
EL. 5.029 m
FISH PASSAGE PORTS

Figure 1. The vertical-slot fishway and surface port structures, after Semple (1984).

History of fish passage opportunities

1968 – A 19-pool vertical-slot fishway was installed during causeway construction, in compliance with the Federal Fisheries Act. Although its design was based on salmonid requirements, it was expected that other fish would also use the fishway.

1969 – Poor fish passage was documented. Physical problems included "reverse flow" of water through fishway at high tides, and poor attraction of fish to the fishway. Flow conditions allowing salmon to pass through open gates were determined (Dominey 1970). Design problems of the fishway are detailed in Riley (1971).

1970-1971 – Discharge patterns were modified to improve attraction flow; gates were opened intermittently.

1971-1972 – Studies indicated that only salmon had better fish passage under normal flows. Salmon, shad, alewives, smelt and striped bass all used the fishway when fishway flow was reversed. In 1972, alewives and smelt passed through the fishway in greatest numbers when fishway flow was reversed.

By 1979 – Significant problems with siltation had further worsened fish passage (Semple 1979; ADI 1979); ADI report recommended modifications to fishway and reductions of leakage through the gates. Semple recommended permanent gate opening.

1983 – Gates were open for much of the season for construction of a water pipeline. One gate was modified to provide attraction flow and an alternate means of passing salmon during certain stages of the tide (the "surface ports", a.k.a. the "stoplog" system, a.k.a. the "bypass notch" – see figure). Leakage through the other gates was sealed. The height of the vertical slot baffle at the entrance to the fishway and the walls of the fishway was increased. The unfortunate result of the fishway alterations was to increase the deadly "blender effect" of reverse tidal flow through the fishway.

1988 – Gates were open for fish passage, April 14-June 7, Sept. 26-Oct. 31; tidal water was allowed to pass upstream.

1989 to early 1990s – Gates were open in May-June at low tide mainly for downstream passage of salmon smolts; tidal water was not permitted to enter headpond.

1998 – Gates were open May 31-June 18 for mud flushing (for planned Trial Gate Opening experiment).

1999 – Gates were open April 8 – June 2 for mud flushing (for planned Trial Gate Opening experiment).

2000 – More modifications to gate operations, intended to increase opportunities for passage through open gates.

What about fish passage through open control gates?

By 1970, the flow conditions necessary for passage of salmon through open gates were identified and it was noted that salmon did not use the fishway when gates were open.

Although in early years of the causeway, the gate openings recommended by fishery scientists were apparently intended to provide attraction flow to bring fish to the fishway rather than directly provide passage, within a decade Semple (1979) wrote that fish passage at the causeway could best be accomplished by complete removal of the causeway gates.

Quite possibly, the gate openings of the past three decades, whether intended for fish passage or for other purposes such as flood control or mud flushing, may be one of the major reasons why there are still residual populations of diadromous species in the system.

The problem of getting fish past an obstacle has been with us a long time. For over two decades, scientists have been suggesting that the best scientific solution to the Petitcodiac problem would be the restoration of natural fish passage (Semple 1979). This is certainly not a novel conclusion. Note the following quotation from Prince, published in **1903**.

> "The conclusion arrived at, after full discussion at the Conference of Dominion Fishery Inspectors, held in Ottawa in April, **1891**, ... that '**wherever a natural pass in a river can be maintained, ... such is to be preferred to any artificial pass**'.
>
> ... After an experience more thorough and extensive than it has probably been the privilege of any other living fishery expert to have, I have come to the conclusion that **the decline in the fisheries in inland water is more directly due to obstructions, natural and artificial, than to any other harmful cause**. Over-fishing, poaching on the breeding grounds, injurious freshets, and similar natural causes, saw-dust, and other pollutions have all worked injury more or less serious, but **none of these compare with the deadly effects of closing the upper waters to the ascent to the schools of spawning fish, and of blocking, by dams, &c., the movements, up and down, of the various migratory species in the young and the adult condition**."

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A FRAMEWORK FOR COOPERATIVE MARINE MONITORING: COLLABORATION BETWEEN GULFWATCH AND ATLANTIC COASTAL ACTION PROGRAM INITIATIVES IN THE BAY OF FUNDY

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A Framework for Cooperative Marine Monitoring (FCMM) for the Bay of Fundy was developed as a tool to facilitate collaboration between Gulfwatch and two Atlantic Coastal Action Program initiatives: ACAP-Saint John and Eastern Charlotte Waterways. Four approaches for collaboration and cooperation were explored in this study: discussion regarding local and regional contaminant monitoring concerns, participation of ACAP members in Gulfwatch mussel (*Mytilus edulis*) monitoring activities, mutual sharing of data and information, and participation in a cooperative multibiomarker-based effects monitoring (MBEM) program as an extension of Gulfwatch.

The overall method used to develop the Framework was participatory research. Informal discussion and a training session were facilitated, mussel collection and sample preparation were conducted jointly, chemical analyses of mussel tissues from selected sites were obtained and interpreted, and experimental evaluation of two promising measures of sub-lethal effects in mussels was conducted. An extensive critical evaluation of measures of sub-lethal effects in mussels was also conducted, and the most promising assays (haemolymph lysosomal neutral red retention, flow cytometric determination of DNA damage, and embryo-larval development and mortality assays) for use in an MBEM program were identified. All of the activities and research supported developing the Framework.

The Framework emphasizes both science and community, with programs and initiatives being common stakeholders generating knowledge, making decisions and taking action. The FCMM also focuses on the use of mussels as one component of an ecological risk assessment of marine contaminants. Other important characteristics of the FCMM include communication, maintaining a flow of information and data and sharing resources of all types between programs. Applying the FCMM is a dynamic and iterative process, allowing the evolution of partnerships to meet new marine monitoring objectives as new contaminant issues arise in the Bay of Fundy.

THE BAY OF FUNDY ECOSYSTEM PARTNERSHIP

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The Bay of Fundy is a productive and diverse coastal ecosystem, rich in renewable resources. However, there are worrisome indications that all is not well within the Bay. Some species and habitats are at risk and the sustainable use of living resources is being compromised. Scientists question the adequacy of their understanding of the ecological processes underlying some of these environmental issues. Sustaining a healthy ecosystem requires cooperation amongst scientists, resource managers, business interests, resource users and residents of coastal communities. The Bay of Fundy Ecosystem Partnership (BoFEP) is a "Virtual Institute" that fosters such cooperative efforts. It is comprised of individuals and groups interested in promoting the conservation, sustainable use and effective management of the marine biota and habitats. The Fundy Marine Ecosystem Science Project (FMESP) is a BoFEP partner that links scientists and environmental managers working in the Bay. BoFEP and FMESP jointly sponsor periodic Bay of Fundy Science Workshops to review progress in our knowledge of the Bay's ecosystem and the challenges confronting it. Several Working Groups, dedicated to specific ecological interests or environmental issues, facilitate communication and cooperation among interested partners. Technical publications, such as Workshop Proceedings and reports on issues, are periodically issued. The Fundy Issues Series provides non-technical overviews of ecological processes and environmental issues in the Bay; to date sixteen topics have been covered. A Website http://www.auracom.com/~bofep provides information about BoFEP and FMESP and their activities, copies of available technical and popular publications and links to information about the Bay of Fundy ecosystem.

BIODIVERSITY OF SUBLITTORAL MARINE INVERTEBRATES IN THE BAY OF FUNDY - FROM THE PERSPECTIVE OF UNDERWATER NATURALISTS

M. Strong and M.-I. Buzeta

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This display provides a snapshot, through the lenses of seven underwater photographers, of the diversity found in underwater world of the Bay of Fundy. For underwater naturalists, each dive offers the thrill of exploring new communities, identifying the diversity of marine species, and the challenge of capturing these images on film. For those that do not dive, we hope that this display will serve as a dry and warm underwater nature trail. Beyond simply exhibiting the obvious beauty found below, we hope to convey a strong awareness of the fragility of this ecosystem, of how poorly it is understood, and of the need for protection of some of these areas.

This photographic display has been touring communities, museums, art galleries and educational facilities around the Bay of Fundy. This project is a joint venture of The Department of Fisheries and Oceans, Oceans Sector and Sundbury Shores Arts and Nature Centre.

UNDERSTANDING ECOLOGICAL CHANGE IN THE BAY OF FUNDY

P.G. Wells

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Utilizing current marine science to distinguish causes and effects of natural and anthropogenic change is required in many coastal areas around the world. The Bay of Fundy in the Gulf of Maine (Northwest Atlantic) has been settled by Europeans for almost 400 years, and offers lessons in this context for coastal science and management. A number of changes have occurred in the Bay over recent years and decades, some natural and some human-induced, and some a combination of the two. Some changes are one-time events (*e.g.* oil and chemical spills, shoreline erosion due to extreme storms) but many, perhaps most of the most important changes, repeat themselves and hence may be cumulative (*e.g.* ocean disposal of harbour sediments, presence of trace chemical substances, sediment build-up below barriers, biomass loss due to fishing). The collective changes and their effects give rise to concern about the welfare of coastal wildlife and other living resources in the Bay, as well as sustained human use. This poster outlines several questions related to understanding ecological change in the Bay, and gives illustrated examples, all in the context of modern approaches in marine ecology, ecotoxicology and other disciplines essential to coastal management. Some challenges are noted for individuals, groups and institutions involved in ecological and environmental monitoring, and preventing or mitigating significant adverse marine ecological change in coastal waters.

THE *COROPHIUM* WORKING GROUP OF BoFEP - CURRENT ACTIVITIES AND FUTURE DIRECTIONS

P.G. Wells and Members of the *Corophium* Working Group

Environment Canada, Ecosystem Science Division, Environmental Conservation Branch,
Dartmouth, Nova Scotia, B2Y 2N6, Canada. peter.wells@ec.gc.ca

The *Corophium* working group (WG) was formed in 1997 as part of the Fundy Marine Ecosystem Science Project, the science arm of the Bay of Fundy Ecosystem Partnership (BoFEP). The WG meets annually to discuss research results and plans, and monitoring initiatives in the Bay of Fundy that deal with the ecology of the amphipod, *Corophium volutator*. This animal is a key species on the mudflats of the upper bay, due to its abundance and its importance as a food resource for migratory shorebirds. The WG currently has 14 members from universities, governments and the private sector in New Brunswick and Nova Scotia. Research focuses on community biology (D. Hamilton, T. Diamond), population ecology and modeling (M. Barbeau), shorebird-amphipod linkages (P.Hicklin), genetics, reproductive biology and parasitism (S. Boates *et al.*), population data analysis (M. Brylinsky, G. Daborn and students), sediment ecotoxicology (K. Doe, P. Wells), bibliography of the literature (P. Wells), and public communication (J. Percy). The WG now has a critical mass of researchers and the opportunity to link studies and share resources to facilitate the research; five members are coordinating their field studies in summer 2000, illustrating the benefits of the WG. In addition, the WG can share data and information, and pursue the goal of developing a comprehensive trophic dynamics model of the role of *Corophium* in the ecology of the mudflats. A plan is developing to have a full session on the biology and ecology of this species at the 5th Bay of Fundy Science Workshop in Wolfville, Nova Scotia, May 2002.

THE IMPORTANCE OF COMMUNICATIONS: THE FUNDY FORUM AS AN EXAMPLE IN THE BAY OF FUNDY

(http://www.fundyforum.com)

M. Westhead

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The Bay of Fundy, shared by New Brunswick and Nova Scotia, Canada, is a beautiful and unique area. Home to the highest tides in the world, it supports a wide variety of activities such as fishing, eco-tourism, whale watching, research, and more. The rich marine waters provide livelihood for many individuals, and the health of the Bay is vital to their traditional way of life.

Communication and information exchange are necessary for a greater understanding of the Bay of Fundy's unique ecosystem and coastal communities. The Fundy Forum, a dynamic web site and email discussion listserver, provides an open and unbiased venue where groups and individuals can gather 'virtually'. Using this technology we can quickly share information and perspectives, identify emerging issues, find common ground, and work collectively for the health of the Bay of Fundy.

The Fundy Forum supports and encourages dialogue, information sharing, partnering opportunities and activities from all walks of life that benefit the health of the Bay of Fundy and its coastal communities. The Fundy Forum gives voice to issues and concerns, lessons learned and successes, opportunities and challenges.

We offer a unique philosophy to our users in that web site and discussion listserver services belong to everyone. What we offer is flexibility and adaptability to meet our user needs. This ensures that we can continue to provide a quality communications network.

BoFEP

ANNUAL GENERAL MEETING

BAY OF FUNDY ECOSYSTEM PARTNERSHIP (BoFEP)

* ANNUAL GENERAL MEETING *

Held at Saint John, New Brunswick on September 20th, 2000
from 5:00 to 7:10 pm

Participants: Graham Daborn, Acadia Centre for Estuarine Research (Chairperson); **Anne Mercer**, Acadia Centre for Estuarine Research; **Jon Percy**, SeaPen; **Barry Jones**, NB Dept. of Environment and Local Government; **Patricia Hinch**, NS Dept. of the Environment; **Max Westhead**, Dept. of Fisheries and Oceans; **Peter Wells**, Environment Canada; **Gerhard Pohle** (for Mark Costello), Huntsman Marine Science Centre; **Thierry Chopin**, UNBSJ; **Tim Hall**, Dept. of Fisheries and Oceans; **Thomas Young**, Resource Management Association; **Donika van Proosdij**, Saint Mary's University/University of Guelph; **Gail Chmura**, McGill University; **Walt van Walsum; Gary W. Saunders**, UNBF; **Bob Maher**, COGS; **Tim Webster**, COGS; **Bill Crossman**, Bay of Fundy Marine Resource Centre; **Kenton (Ken) E. Kinney**, NB Dept. of the Environment and Local Government; **Sean Brillant**, ACAP Saint John; **Hugh Akagi**, Passamaquoddy First Nation; **Philip Holmes**, SCEP; **Colin R. Bates**, UNBF; **Joan Reid**, DFO-Habitat; **Stephanie Astephen**, DFO-Habitat; **Ted Cavanagh**, Architectural Planning – Dalhousie Integrated Coastal Planning Project; **Larry Hildebrand**, Environment Canada; **Shawn Dalton**, John Hopkins University, Baltimore Ecosystem Study; **Deb MacLatchy**, UNBSJ; **Jamey Smith**, Coastal Smith Inc.; **Mike Butler**, Oceans Institute; **Claudette LeBlanc**, ACZISC Secretariat; **Paula Noel**, Irving Nature Park Saint John; **Won Oh Song**, Korea Ocean Research and Development Institute; **David Thompson**, CCNB; **Tony M. Bowron**, Ecology Action Centre; **David Greenberg**, Bedford Institute of Oceanography, **Jeff Ollerhead**, Mount Allison University.

Regrets: Alison Evans, Arthur Bull, David Coon, Maria-Inez Buzeta and Steve Hawboldt.

1. **Call to order** (G. Daborn in Chair)

The Chair explained that this is not a "founding meeting" in the true sense, but rather an attempt to provide BoFEP with a somewhat more formal framework than it has thus far had. A description of what BoFEP does and what it entails was provided. Stated that BoFEP provides a mechanism to link all the various organizations around the Bay of Fundy and membership is open to anyone interested, concerned with and involved in the Bay of Fundy.

2. Approval of minutes of AGM on April 24th, 1999 in Sackville, New Brunswick.

Errors or omissions

- Participants' names - Robin Davidson-Anwott should be Robin Davidson-Arnott
- Item 4 – BoFEP Working Groups: P.G. Wells stated that the Tidal Restrictions Working Group includes Janice Harvey along with himself.
- Item 5 – BoFEP Officers and Structure: J. Percy should also be referred to as Coordinator as well as Webmaster.

Motion to accept minutes as corrected
B. Jones - Carried

Matters arising from the minutes of April 24th, 1999

Action Item 1: Mick Burt agreed to develop some definition of a "consortium" concept for our next meeting. There has been no word from Mick Burt on this.

Action Item 2: Barry Jones was to look into BoFEP possibly seeking a permanent seat on the Gulf of Maine Council on the Marine Environment Working Group. Barry Jones indicated that they will keep the *status quo* for now, but this doesn't preclude us having a permanent seat at table in the future. It may be an option to become a "Friend of the GOMC" through the GOMC's establishing the Gulf of Maine Friends Group. Noted that the GPAC group is looking at having a structural relationship between the two groups (GPAC and BoFEP?). If BoFEP wants to establish such a relationship needs to approach the GOMC to suggest structural linkages. ***Action Item #1: Barry Jones will provide information on this that GOMC Working Group receives. Steering Committee to deal with this item in the future.***

Action Item 3: Peter Wells agreed to look into possible funding for the website, proceedings, fact sheets, etc. Peter Wells noted that there has been extensive funding for BoFEP from Environment Canada and support from DFO for various communication products. The chairman acknowledged that there has been a great deal of financial support from both EC and DFO and this has largely kept BoFEP going.

3. Adoption of BoFEP draft constitution

The draft constitution was presented for discussion and amendment. Graham Daborn gave an update of the reason for this constitution and explained that we need formal structure to create an entity in order to obtain funding order to carry on our work.

Article 1:
Change to: "*includes the full Bay seaward as an integral part of the Gulf of Maine*".

Article 4:
It was questioned how organizational and individual memberships differ and discussion took place on this.
The following changes were made to this article:
Change to "*......any individual or representative of an organization.....*"
Change to: "*.....supports the Purpose of the Partnership and reconfirms such membership from time to time as required by the Steering Committee.*"

Article 5:
Steering Committee members are elected at the AGM. Discussion about manner of voting for members of Steering Committee: should various constituencies within the organization vote only for their own representatives? Do we really want to make the structure this formal at this point? Consensus is that we continue with an open election procedure for the time being. If the need arises we can establish a more formal voting procedure in the future. We should include an additional statement about the possibility of nominations from the floor at the AGM - in addition to the slate proposed by the nominating committee. Question as to whether we should specify maximum number of terms that Steering Committee members can serve? At this stage in evolution of organization probably best not to limit willing volunteers. Question as to whether we need a mechanism for resigning from committee and for removing someone from committee. Felt that it was not necessary to spell this out. Normal term of the Steering Committee will be until next AGM.
Change to: *"Steering Committee members will serve until the next Annual General Meeting. There will be no remuneration for Steering Committee members."*

Article 6:
Take out last six words in Article: "*..... until the next Annual General Meeting.*"

Article 7:
Discussion took place on how often the Management Committee should meet and is there a requirement to meet? Due to the unincorporated status of the organization this is not an issue and will merely be a set of guidelines put in place.

Motion to adopt constitution as amended
B. Jones/L. Hildebrand
Carried

4. Reports from Working Groups

Brief reports were presented by several of the Working Group chairs present regarding recent activities of their groups. Several of the groups are now fully active. Others are still getting themselves organized. Details about the Working Groups and their composition and activities are available on the BoFEP Website (http://www.auracom.com/~bofep).

5. Activities and work plan

This item was tabled to the next BoFEP Steering Committee Meeting.

6. Election of Steering Committee

The Nominating Committee proposed that the following be elected to the Steering Committee for the coming year:

Hugh Akagi, Sean Brillant, Arthur Bull, Michael Butler, Gail Chmura, Thierry Chopin, David Coon, Mark Costello, Graham Daborn, Tim Hall, Stephen Hawboldt, Peter Hicklin, Larry Hildebrand, Pat Hinch, Barry Jones, Anne Mercer, David Mossman, Jeff Ollerhead, Jon Percy, Maria Recchia, Peter Wells, Maxine Westhead and Thomas Young.

One vacancy to be filled by Steering Committee.

Motion to accept proposed Steering Committee
Tim Hall - Carried

7. Other Business

Recommendation that the next AGM meeting be held in May 2001. The 2002 AGM would also be held in May to coincide with the BoFEP Science Workshop to be held in Wolfville. Jon Percy sought and received agreement in principle to explore the possibility of holding a BoFEP Science Workshop in Annapolis Royal in 2005 to coincide with celebrations of the 400th Anniversary of European settlement of the area, with a theme oriented to 400 years of change in the Bay of Fundy.

8. Adjournment

The Annual General Meeting was adjourned at 7:10 pm.

BoFEP CONSTITUTION

Article 1 – Status

The organization is called the Bay of Fundy Ecosystem Partnership, and is a non-profit, non-partisan and non-sectarian organization which functions as a forum of equal partners. It serves the Bay of Fundy drainage area landward, and includes the full bay seaward as an integral part of the Gulf of Maine.

Article 2 – Purpose

The Partnership envisions the future in which the Bay of Fundy and its communities are environmentally, economically and socially sustainable, and its mission is to promote the long-term viability of this ecosystem.

Article 3 – Structure

The structure of the Partnership shall consist of an Annual General Meeting of its Membership, a Steering Committee and a Management Committee. The Steering Committee may retain secretariat services, including a Partnership Coordinator and other support personnel as finances allow.

Article 4 – Membership

The Membership shall consist of any individual or representative of an organization that registers as such and supports the Purpose of the Partnership and reconfirms such membership from time to time as required by the Steering Committee. It shall hold an Annual General Meeting within the Bay of Fundy area to decide upon Partnership philosophy, amendments to the Constitution, By-Laws and strategic goals, to approve annual operational reports and elect the Steering Committee. The quorum for Annual General Meetings shall consist of 50 members or 20% of the recorded membership, whichever is the lesser.

Article 5 – Steering Committee

Accountable to the Annual General Meeting, the Steering Committee shall consist of not more than 24 members, and be representative of all partners, including community groups, academics, business/industry, First Nations, non-government organizations and federal, provincial and municipal governments; all interim vacancies to be filled by the Steering Committee. It is responsible for ensuring that Partnership decisions are in line with Partnership philosophy, for adopting policies and strategies, and for establishing committees. Steering Committee members will serve until the next Annual General Meeting. There will be no remuneration for Steering Committee members. The quorum for its meetings shall consist of half the number of its elected members, with 2 weeks notice given.

Article 6 – Officers

There shall be four Officers of the Partnership, namely Chair, Vice-Chair, Secretary and Treasurer. They shall be elected by the Steering Committee from among its members at a meeting immediately following each Annual General Meeting, and shall serve as such without remuneration.

Article 7 – Management Committee

Accountable to the Steering Committee, the Management Committee consists of the four Partnership Officers and three other Steering Committee representatives elected by and from the Steering Committee. In accordance with the policies approved by the Steering Committee, the Management Committee is responsible for recommending and ensuring implementation of the general orientation, strategies and action plans of the Partnership. It also ensures the efficient management of resources, projects and services, and other operations of the Partnership. The quorum for Management Committee meetings shall consist of four members.

Article 8 – Decision Making

All issues addressed by the Partnership will be decided by consensus (by general agreement), except for the election of Steering Committee members, Officers and other Management Committee members, and amendments to the Constitution and any By-Laws, which shall be considered voting matters.

Article 9 – Borrowing Powers

The Partnership shall have no borrowing powers, nor will any of its Membership, committees, representatives or staff on its behalf.

Article 10 – Financial Books, Records and Meeting Minutes

The financial books, records and meeting minutes of the Partnership may be inspected by any of the Membership at any reasonable time with seven days prior written notice to the Secretary at the registered office of the Partnership.

Article 11 – Constitution and By-Laws

The Partnership may amend its Constitution and establish and amend any By-Laws by a 2/3 majority of the members voting at Annual General Meetings, provided that prior 30 day notice of such changes has been given to the Membership.

APPENDIX:

PROGRAMME

Tuesday, September 19, 2000

Case Studies/Workshops (1:30pm – 4:30pm)

Session 1: Nutrification of Coastal Waters
Location: Montagu II
Organizer: T. Chopin, University of New Brunswick, Saint John, New Brunswick, Canada

13:30 – 13:45 Introduction
T. Chopin
University of New Brunswick, Saint John, New Brunswick, Canada

13:45 – 14:10 Nutrient Over-Enrichment of Coral Reefs in the Florida Keys: How Science And Management Failed to Protect a National Treasure
B.E. Lapointe
Harbor Branch Oceanographic Institution, Fort Pierce, Florida, USA

14:10 – 14:35 The Health of the Rio de la Plata System: Northern Coast, Uruguay
M. Gomez-Erache, D. Vizziano, P. Muniz and G.J. Nagy
Universidad de la Republica, Montevideo, Uruguay

14:35 – 15:00 Nutrient Dynamics in Inlets in the Maritimes
P. Strain
Department of Fisheries and Oceans, Dartmouth, Nova Scotia, Canada

15:00 – 15:15 Afternoon Nutrition Break

15:15 – 15:40 An Overview of Circulation and Mixing in the Bay of Fundy and Adjacent Areas
F. Page
Department of Fisheries and Oceans, St. Andrews, New Brunswick, Canada

15:40 – 16:05 The Role of Seaweeds in Integrated Aquaculture and their Contribution to Nutrient Bioremediation of Coastal Waters
T. Chopin[1], C. Yarish[2], G. Sharp[3], C. Neefus[4], G. Kraemer[5], J. Zertuche-Gonzalez[6], E. Belyea[1] and R. Carmona[2]
[1]University of New Brunswick, Saint John, New Brunswick, Canada
[2]University of Connecticut, Stamford, Connecticut, USA
[3]Department of Fisheries and Oceans, Dartmouth, Nova Scotia, Canada
[4]University of New Hampshire, Durham, New Hampshire, USA
[5]State University of New York, Purchase, New York, USA
[6]Universidad Autonoma de Baja California, Ensenada, Baja California, Mexico

16:05 – 16:30 Round Table Discussion/Recommendation

Session 2: Tidal Power Development – Environmental Issues and Constraints

Location: **Montagu III**
Organizer: **K. Sollows, University of New Brunswick, Saint John, New Brunswick, Canada**

13:30 – 13:45 Introduction and Overview of the Environmental and Economic Impacts of Non-Tidal Energy Technologies
K.F. Sollows
University of New Brunswick, Saint John, New Brunswick, Canada

13:45 – 14:20 Review of Engineering Studies on Tidal Power, Technical/Economic Performance of Existing Plants, and Scenario for the Bay of Fundy
E. van Walsum
Pointe Claire, Quebec, Canada

14:20 – 15:00 Tidal Power Development - Environmental Issues and Constraints
G.R. Daborn and M. Dadswell
Acadia University, Wolfville, Nova Scotia, Canada

15:00 – 15:15 Afternoon Nutrition Break

15:15 – 16:30 Round Table Discussion/Recommendation

Session 3: Ecologically and Community Valued Marine Areas in the Bay of Fundy (Criteria for MPA Site Identification and Selection)

Location: **Montagu I**

Organizers: **D. Fenton, Department of Fisheries and Oceans, Dartmouth, Nova Scotia, Canada**
M.-I. Buzeta, Department of Fisheries and Oceans, St. Andrews, New Brunswick, Canada

13:30 – 13:40 Introduction
D. Fenton[1] and M.-I. Buzeta[2]
[1]Department of Fisheries and Oceans, Dartmouth, Nova Scotia, Canada
[2]Department of Fisheries and Oceans, St. Andrews, New Brunswick, Canada

13:40 – 13:55 MPA Introduction and DFO's Efforts in the Bay of Fundy
M.-I. Buzeta
Department of Fisheries and Oceans, St. Andrews, New Brunswick, Canada

13:55 – 14:10 What is the Objective of a Network of MPAs – National and International Perspectives
B. Barr
NOAA's National Marine Sanctuary Program, Woods Hole, Massachusetts, USA

14:10 – 14:25 The Role of Science (Biodiversity Indices) in Site Selection and Setting of Boundaries, Decision Making, and Development of Management Plans
M.J. Costello
Huntsman Marine Science Centre, St. Andrews, New Brunswick, Canada

14:25 – 15:00 Community Involvement and Role in Identifying Sites
J. Harvey
Conservation Council of New Brunswick, Waweig, New Brunswick, Canada

15:00 – 15:15 Afternoon Nutrition Break

15:15 – 15:40 Background References for Setting Criteria, Results from Various Discussions, and Worldwide Standards
D. Fenton
Department of Fisheries and Oceans, Dartmouth, Nova Scotia, Canada

15:40 – 16:30 Round Table Discussion/Recommendation

Wednesday, September 20, 2000

Paper Presentations (10:00am – 12:00pm)

Session 1: Bay of Fundy – Science and Tools
Location: Montagu II & III
Chair: T. Chopin, University of New Brunswick, Saint John, New Brunswick, Canada

10:00 – 10:20 Shorebirds, Snails, and *Corophium*: Complex Interactions on an Intertidal Mudflat
D.J. Hamilton[1,2] and A.W. Diamond[1]
[1]Atlantic Cooperative Wildlife Ecology Research Network
[2]University of New Brunswick, Fredericton, New Brunswick, Canada

10:20 – 10:40 Modeling Initiatives in the Bay of Fundy
D.A. Greenberg
Department of Fisheries and Oceans, Dartmouth, Nova Scotia, Canada

10:40 – 11:00 Simple Bio-Economic Modeling as a Predictor of Estimating Harvest Potential and Economic Value of Soft-Shell Clam (*Mya arenaria*) Resources in Southwestern New Brunswick, Canada
K.L. LeBlanc
Eastern Charlotte Waterways Inc., St. George, New Brunswick, Canada

11:00 – 11:20 Lunar-Powered Aquaculture. The Use of Tidal Pumping in Land-Based Fish Farms
K. Waiwood
LandSea Culture Systems, Chamcook, New Brunswick, Canada

11:20 – 11:40 High Resolution Imaging and Terrain Extraction Along the Bay of Fundy Coastal Zone, Nova Scotia, Canada
T. Webster and R. Maher
Nova Scotia Community College, Middleton, Nova Scotia, Canada

11:40 – 12:00 The Use of Geographic Information Systems for Coastal Zone Management. Cobscook Bay, Maine. A Case Study
M. Kostiuk
Carleton University, Ottawa, Ontario, Canada

Wednesday, September 20, 2000

Paper Presentations (1:10pm – 4:50pm)

Session 2: Communities, Contaminants and Habitats
Location: Montagu I, II & III
Chair: T. Chopin, University of New Brunswick, Saint John, New Brunswick, Canada

1:10 – 1:30 Marine Environmental Quality (MEQ) Framework and the Bay of Fundy
C.P. Chang[1] and P.G. Wells[2]
[1]Dalhousie University, Halifax, Nova Scotia, Canada
[2]Environment Canada, Dartmouth, Nova Scotia, Canada

1:30 – 1:50 Beyond Environmental Management: The Wider Community of Participatory Design, Social Science and Professional Planning
A. Evans and T. Cavanagh
Dalhousie University, Halifax, Nova Scotia, Canada

1:50 – 2:10 The Marine Food Web in Relation to the Movement and Accumulation of Toxins in Saint John Harbour, New Brunswick, Canada
S. Brillant[1], M.H.L. Thomas[2] and T. Chopin[2]
[1]ACAP Saint John, Saint John, New Brunswick, Canada
[2]University of New Brunswick, Saint John, New Brunswick, Canada

2:10 – 2:30 Letang Inlet: Long Term Far-Field Monitoring and Assessment of Benthos in an Area with Nutrient Loading
G. Pohle
Huntsman Marine Science Centre, St. Andrews, New Brunswick, Canada

2:30 – 2:50 Estuary + Causeway = Species, Populations and Habitats Lost in the Petitcodiac River
A. Locke[1], J.M. Hanson[1], S. Richardson[1,2], I. Aube[1,2] and G. Klassen[3]
[1]Department of Fisheries and Oceans, Moncton, New Brunswick, Canada
[2]Dalhousie University, Halifax, Nova Scotia, Canada
[3]University of New Brunswick, Saint John, New Brunswick, Canada

2:50 – 3:10 Afternoon Nutrition Break

Chair: P.G.Wells, Environment Canada, Dartmouth, Nova Scotia, Canada

3:10 – 3:30	The Effects of Azamethiphos on Survival and Spawning Success in Female American Lobsters (*Homarus americanus*) L.E. Burridge, K. Haya and S.L. Waddy Department of Fisheries and Oceans, St. Andrews, New Brunswick, Canada
3:30 – 3:50	High Copper Contamination in Lobster from the Inner Bay of Fundy and Saint John Harbour, Canada C.L. Chou, L.A. Paon, J.D. Moffatt and B.M. Zwicker Department of Fisheries and Oceans, Dartmouth, Nova Scotia, Canada
3:50 – 4:10	Dioxins/Furans and Chlorobiphenyls in *Mytilus edulis* from the Gulf of Maine P. Hennigar, M. Chase, G. Harding, S. Jones, J. Sowles and P.G. Wells Environment Canada, Dartmouth, Nova Scotia, Canada
4:10 – 4:30	Strategies for a sustainable management of the brown seaweed *Ascophyllum nodosum* (rockweed) R.A. Ugarte Acadian Seaplants Limited, Dartmouth, Nova Scotia, Canada
4:30 – 4:50	Use of Mesocosms for Monitoring in Complex Estuarine Environments: A Case Study from the Saint John Harbour, Bay of Fundy D. MacLatchy[1], M. Dube[1,2], J. Culp[2] and K. LeBlanc[1,3] [1]University of New Brunswick, Saint John, New Brunswick, Canada [2]Environment Canada, Saskatoon, Saskatchewan, Canada [3]Eastern Charlotte Waterways Inc., St. George, New Brunswick, Canada

Wednesday, September 20, 2000

Annual General Meeting of BoFEP (5:00pm – 7:00pm)

Location: **Montagu I, II & III**

Thursday, September 21, 2000

Paper Presentations (10:00am – 12:00pm)

Session 3: Salt Marshes and Reserves
Location: Montagu I, II & III
Chair: J. Percy, Clean Annapolis River Project, Granville Ferry, Nova Scotia, Canada

10:00 – 10:20 Two Centuries of Wetland Plant Community Variability in Bay of Fundy Salt Marshes: A Paleoecological Study
C.B. Beecher and G.L. Chmura
McGill University, Montreal, Quebec, Canada

10:20 – 10:40 Conservation of Wildlife Habitat in the Agricultural Landscape of the Tantramar Dykelands
S. Bowes
Department of Natural Resources, Sackville, New Brunswick, Canada

10:40 – 11:00 An Assessment of Arcview 3.1 and Image Analysis 1.0 as Tools for Measuring Geomorphic Change at Three Bay of Fundy Saltmarshes
J. Ollerhead[1] and R. Rush[2]
[1]Mount Allison University, Sackville, New Brunswick, Canada
[2]University of Guelph, Guelph, Ontario, Canada

11:00 – 11:20 Annual and Seasonal Variations in Erosion and Accretion in a Macro-Tidal Saltmarsh, Bay of Fundy
D. van Proosdij[1,2], J. Ollerhead[3] and R.G.D. Davidson-Arnott[2]
[1]Saint Mary's University, Halifax, Nova Scotia, Canada
[2]University of Guelph, Guelph, Ontario, Canada
[3]Mount Allison University, Sackville, New Brunswick, Canada

11:20 – 11:40 Taking the Time to Get it Right: Community-Based Salt Marsh Restoration Work in Nova Scotia
T.M. Bowron, J. Graham and M. Butler
Ecology Action Centre, Halifax, Nova Scotia, Canada

11:40 – 12:00 Moving Towards a Coastal Biosphere Reserve in Atlantic Canada - Some Lessons from the Scotian Coastal Plain
M. Ravindra
St. Lawrence Islands National Park, Mallorytown, Ontario, Canada

BoFEP POSTERS

Location: Loyalist Room

1) Monitoring Seaweed Diversity in the Bay of Fundy, New Brunswick, Canada
   C.R. Bates[1], T. Chopin[2] and G.W. Saunders[1]
   [1]University of New Brunswick, Fredericton, New Brunswick, Canada
   [2]University of New Brunswick, Saint John, New Brunswick, Canada

2) Oceanography and other Studies in Musquash – A Proposed Marine Protected Area
   M.-I. Buzeta, M. Strong, F. Page, M. Dowd, J.L. Martin and M. LeGresley
   Department of Fisheries and Oceans, St. Andrews, New Brunswick, Canada

3) Fundamentals of Fundy Tides
   C. Desplanque[1] and D.J. Mossman[2]
   [1]Amherst, Nova Scotia, Canada
   [2]Mount Allison University, Sackville, New Brunswick, Canada

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